Motor Control Daughter Board

Revision 3.0

User's Manual

Revision History

Date	Version	Description	Author
09/08/2006	1.0	Revision 1.0 Preliminary Document	Shivachandra Javalagi Ishnatek Systems
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0.0 Before Starting

0.1 Safety Warnings

0.1.1 General

In operation, the Motor Control Kit has un-insulated wires, moving or rotating parts as well as hot surfaces. In case of improper use, wrong installation or mal-operation, there is danger of serious personal injury and damage to property. All operations, installation and maintenance are to be carried out by skilled technical personnel (national accident prevention rules must be observed).

When the Motor Control board is supplied with voltages greater than 24 V AC/DC, all of the board and components must be considered "hot", and any contact with the board must be avoided. The operator should stay away from the board as well (risk of projection of material in case of components destruction, especially when powering the board with high voltages). The rotating parts of motors are also a source of danger. Never try to stop the motor by holding the rotating shaft by hand.

The Motor Control Kit contains electrostatic sensitive components which may be damaged through improper use.

0.1.2 Intended Use

The ISH-ACT-MCK Starter Kit is made of components designed for demonstration purposes and must not be included in electrical installations or machinery. Instructions about the setup and use of the ISH-ACT-MCK Starter Kit must be strictly observed at all times.

0.1.3 Operation

After disconnecting the board from the voltage supply, several parts and power terminals must not be touched immediately because of possible energized capacitors or hot surfaces.

0.1.4 Important Notice to Users

While every effort has been made to ensure the accuracy of all information in this document, Ishnatek Systems and Actel assumes no liability to any party for any loss or damage caused by errors or omissions or by statements of any kind in this document, its updates, supplements, or special editions, whether such errors are omissions or statements resulting from negligence, accident, or any other cause.

0.2 Required Skills

In order to profitably use the ISH-MCDB-R3 Motor Control Starter Kit, you should be acquainted with several skills, ranging from hardware design to software design. In particular, you should possess the knowledge about Electrical Motors and FPGA Programming.

1.0 Introduction:

Features:

- Supports
  - Stepper Motor (4-Wire, 5-Wire as well as 6-Wire Configuration)
    - Full Step / Half Step Mode
    - Micro Step Mode (Sinusoidal / Trapezoidal Option)
    - 8 / 16 / 32 Microsteps
  - Brushless DC (BLDC) Motor (Provision for 4- One Phase or 2 –Two Phase or 1 – Three Phase OR 1 – Four Phase BLDC Motor)
    - Sensored Drive
      - Using Hall Effect Sensors provided on Motors
    - Sensorless Drive
      - Using on board comparators OR
      - Using Fusion ADC threshold flags
  - Brushed Drive
    - Support One Brushed Motor with Direction/Speed Control
- Direction Control – Clockwise or Counterclockwise Rotation
- Basic Functions
  - Start
  - Stop
  - Step (Full or Half Stepping in case of Stepper Motor)
  - RPM+/RPM- (Increase/Decrease RPM)
  - Analog/Digital Control Features
- Four Acceleration Settings for various motor types
  - Fast (208 milliseconds)
  - Medium High (312 milliseconds)
  - Medium Low (520 milliseconds)
  - Slow (3.74 seconds)
- Support Four PWM Modes
  - PWM on high side of Mosfet Bridge
  - PWM on low side of Mosfet Bridge
  - PWM on both sides of Mosfet Bridge
  - Complementary through Mosfet Bridge (BETA –Feature)
- Hardware/Software Control
  - Access to all above features through keys/switches on board
  - Equivalent controls are provided also through software
  - Software Interface using on-board USB-to-RS232 bridge
- High Output Current up to 10A
- Over Current/Over Temperature Protection through Shutdown Pin of the Mosfet Driver.

2. Contents and System Requirements

- Motor Control Daughter Board – Rev 3.0

- Requirements:
  - Fusion Starter Kit (AFS600FG256ES) (Not Provided)
  - 40 Pin FRC Connector (To Fusion Starter Kit, Provided)
  - 12 Pin Straight Connector (To Fusion Starter Kit, Provided)
  - 4 Pin Straight Connector (To Fusion Starter Kit, Provided)
  - Baud Rate Select Cable (to Fusion Starter Kit, Provided)
  - BLDC Motor – Maxon EC-45 Flat (Provided - Appendix B for Details)
  - Stepper Motor – Hybrid Stepping Motor 14HY5401 (Provided - Appendix B for Details)
  - Motor and Reference Power Supply (Dual Output) (Provided)
    - 12V, 5A (Motor Power Supply)
    - 12V, 2A (Reference Power Supply)

- Software Requirements:
  - USB Cable (Provided)
  - Motor Control Software and USB Drivers (Provided)
  - Operating System - Windows XP or Higher Required

- Fusion STP Files (Provided)
  There are 2 versions of STP files available depending on the feature set as described below
  - mcdb_rev3_adc_drive.stp (This version does not support temperature and current sense features)
  - mcdb_rev3_ts_cs.stp (This version does not support BEMF drive using Fusion ADC)

  Apart from the above differences both version supports all the other features as described in the introduction.

3. Connection steps and Precaution

3.1 Connection steps

Please follow the steps carefully in order to avoid damage to Fusion Board:
Make sure the power to Fusion Kit and the Motor Control Kit are OFF.

3.1.1. Important Pre-Connection Checks**:**

Make sure the AC input voltage switch on Kit is set to 110V (If not open the back lid of the kit and change it to 110V). Don't Plug the Power Supply cord in yet.

3.1.2. Fusion Starter Kit Setup:

Remove the following short-links on the Fusion Starter Kit, JP51, JP49, JP68, JP62, JP34, JP30 and JP37

3.1.2.1 RPM Control using Analog Potentiometer:

A Potentiometer connected to Pin AV0 and to Fusion Pin 'M6' (On the Fusion Kit) can be used to control the speed when in analog control mode.

3.1.2.2 Connections for BEMF drive using Fusion ADC (If Fusion Kit is programmed with **mcdb_rev3_adc_drive.stp**)

Remove Jumpers JP34 ('M9'), JP30 ('N7') and JP37 ('N9') on Fusion Board
Daughter Board Checks:

- JP14, JP15, JP16 and JP17 on daughter board are closed – Scaled Motor Voltages
- Pin 12 of J5 on daughter board connects to Fusion pin 'M9' by removing jumper 'JP34' on FUSION board.
- Pin 11 of J5 on daughter board connects to Fusion pin 'N7' by removing jumper 'JP30' on FUSION board.
- Pin 10 of J5 on daughter board connects to Fusion pin 'N9' by removing jumper 'JP37' on FUSION board .

CABLE D – (4 – Open single Leads) (**Orange** left unconnected)

Wire From Daughter Board	Color Code (CABLE - D)	Fusion Pin
Pin 12 of J5 (PH_A_BEMF)	**Black**	M9
Pin 11 of J5 (PH_B_BEMF)	**Brown**	N7
Pin 10 of J5 (PH_C_BEMF)	**Red**	N9

3.1.2.3 Connections for current sensing: (If Fusion Kit is programmed with **mcdb_rev3_ts_cs.stp**)

Remove Jumpers JP51 and JP49 on Fusion Board

Daughter Board Checks:

- JP20 and JP21 on daughter board are closed – Current Sense
- Pin3 of J6 (VM_CS_OUT) on daughter board connects to Fusion Pin 'M7' by removing jumper JP51 on Fusion Board (Pin 2 of JP51)
- Pin 4 of J6 (VM_LOW_OUT) on daughter board connects to Fusion Pin 'P6' by removing jumper JP49 on FUSION board (Pin 2 of JP49)

Wire From Daughter Board	Board Pin Names	Color Code (CABLE - C)	Fusion Pin
Pin3 of J6	VM_CS_OUT	**Brown**	M7 (Pin 2 of JP51)
Pin 4 of J6	VM_LOW_OUT	**Black**	P6 (Pin 2 of JP49)

There is sense resistor Rs (10 milliohm) provided on the low side of the power drive. The current that flows through this sense resistor is discontinuous as the signal is chopped at the PWM frequency. The current flows during the ON time of the power stage and is zero during the OFF time. If you need to measure average current you will need to create your own hardware. This feature is not supported on the daughter board.

3.1.2.4 Connections for Temperature Sensing: (If Fusion Kit is programmed with mcdb_rev3_ts_cs.stp)

Remove Jumpers JP68 and JP62 on Fusion Board

Daughter Board Checks:

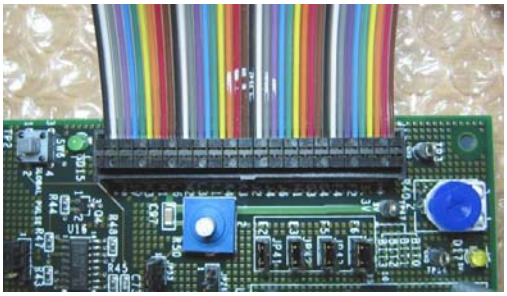
- JP18 and JP19 on daughter board are closed – Temperature Sense
- Pin 1 of J6 (T_RTN) on daughter card connects to Fusion pin 'R12' by removing jumper 'JP62' on FUSION board. (Pin 2 of JP62)
- Pin 2 of J6 (T_SIG) on daughter card connects to Fusion pin 'T12' by removing jumper 'JP68' on FUSION board. (Pin 2of JP68)

Wire From Daughter Board	Board Pin Names	Color Code (CABLE - C)	Fusion Pin
Pin1 of J6	T_RTN	**Orange**	R12 (Pin 2of JP62)
Pin 2 of J6	T_SIG	**Red**	T12 (Pin 2of JP68)

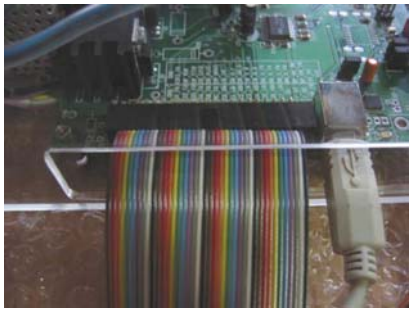
Note that the temperature sensing method used is quite susceptible to Noise. For higher accuracy it is necessary to use high resolution temperature sensors which are not susceptible to noise. To filter out the noise connect a capacitor of value 10nF between Pins R12 and T12 of fusion board.

3.2 Connection Details :

3.2.1 Connect the 40 Pin Connector – Pin1 should match on the Fusion Side and the Board side. This cable does not have polarization and it could go in either way, hence it is very important that the marking should be matched perfectly else this would cause damage to the board. A 'Silver' colored dot indicates Pin 1 on the connector. Make sure these match perfectly before turning on the Board (Warning: You could blow up the board if this is not done right) **Black - Pin 40 and Dark Brown is Pin 1**



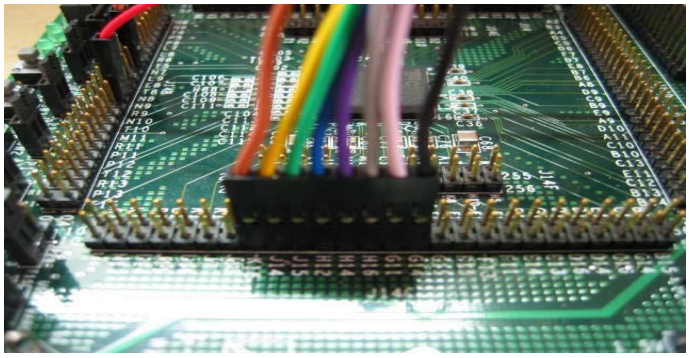
Pin 1 of 40 Pin Cable goes to Pin 1 of J13 on Fusion Side (Match the Silver Dot for Pin 1 on both sides



Pin 1 of 40 Pin Cable goes to Pin 1 of J4 on Motor Control Board Side (Match the Silver Dot for Pin 1 on both sides

3.2.2 The extra 8-wire connector (CABLE - D) should be connected to Fusion board as per table below.

Wire from	Wire to	Color	Signal name	Dip switch pin no.	FUSION pin
10-way DIP on daughter card	FUSION board	**Brown**	MST_SC_OR_PWM	3	K16
		Yellow	PWM_freq_sel[1]	10	J14
		Green	PWM_freq_sel[0]	9	J15
		Blue	NO_MSTP_OR_BL_MD[1]	8	H12
		Purple	NO_MSTP_OR_BL_MD[0]	7	H14
		Gray	Acceleration time[1]	6	H16
		White	Acceleration time[0]	5	G11
		Black	Stepper_range	4	G14



3.2.3 Baud Rate Selection:

The baud rate wires may be left **unconnected**, they have internal pull-ups and have been programmed to **9600** baud rate. If you want to change the baud rate for serial communication then you can connect these as per the data sheet that follows. Keep same baud rate setting for hardware as well as software.

Wire From	Wire To	Color Code (Baud Rate Select Cable)	Fusion Pin
Baudclock reg [2]	As per baud rate selection table below GND or VDD	**Orange**	H11
Baudclock reg [1]		**Yellow**	H13
Baudclock reg [0]		**White**	H15

3.2.4 *Baud Rate selection table*

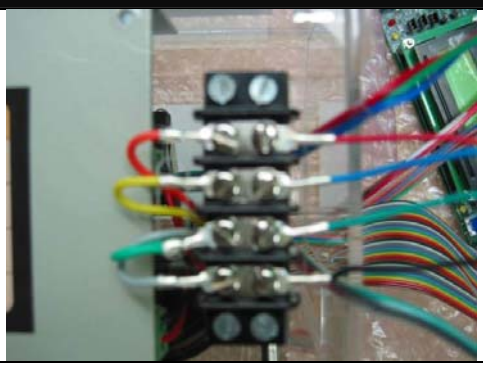
Baudclock reg [2] Orange	Baudclock reg [1] Yellow	Baudclock reg [0] White	BAUDRATE
0	0	0	1220
0	0	1	2440
0	1	0	4880
0	1	1	9600
1	0	0	19200
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

For more macro view you may look at additional pictures available in Appendix D.

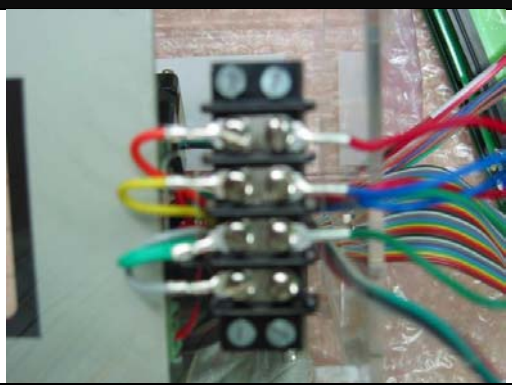
3.2.5 Motor Connections

You can either connect a Stepper Motor (4 –Wire) or a BLDC Motor (3 Phases) to the back panel provided on the kit as below to the back:

3.2.5.1 ***Stepper Motor Connections***: (CABLE-F, 4 Wires)

	Original wire/leads on the motor	Motor Connections	
Phase 'A'	**Red**	MOT_A (To Back Panel)	
Phase 'B'	**Blue**	MOT_B (To Back Panel)	
Phase 'C'	**Green**	MOT_C (To Back Panel)	
Phase 'D'	**Black**	MOT_D (To Back Panel)	

3.2.5.2 ***BLDC Motor Connections:*** (CABLE-E, 3 wires)

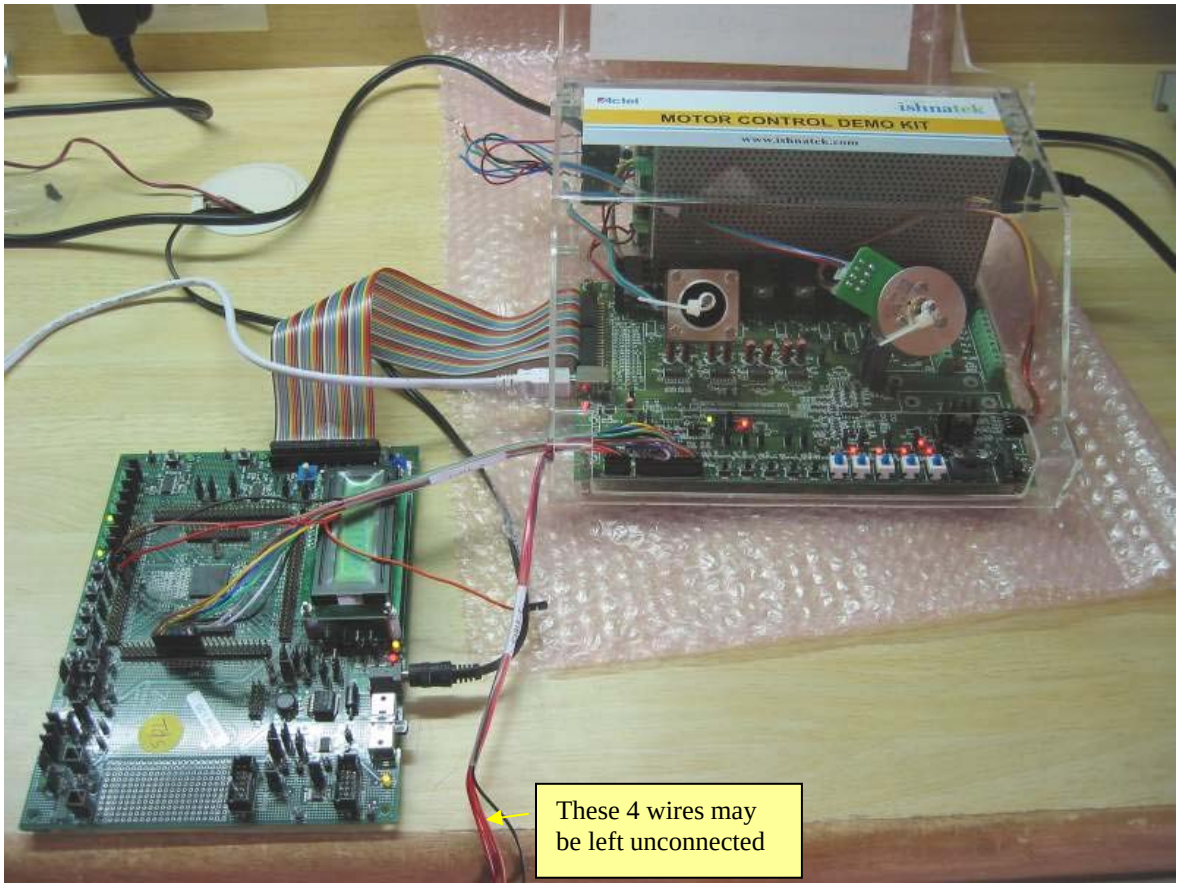
	Color Code	Motor Connections	
Phase 'A'	**Red**	MOT_A (To Back Panel)	
Phase 'B'	**Blue**	MOT_B (To Back Panel)	
Phase 'C'	**Green**	MOT_C (To Back Panel)	

Note: Only one motor can be connected to the back panel.

For sensorless operation it is not necessary to remove the Hall connections.

3.3 Precaution

After making connections as per instructions and wiring diagram given take the following steps for turning ON or OFF the connections to the kit. These steps should be followed strictly to protect the boards.



WARNING!

In order to protect the I/O's of the Fusion Part a proper Power up and Power Down sequence has to be followed. This will ensure that there is no back-power from the daughter board to fusion board and hence protect the I/O's.

Kit Power Up Sequence:

Step 1: Power up Fusion Board
Step 2: Power up Motor Control Kit

Kit Power Down Sequence:

Step 1: Power Down Motor Control Kit
Step 2: Power Down Fusion Board

4 Operational Settings

4.1 BLDC Acceleration Settings:

In the current setup, for Maxon EC45 Flat, use MEDIUM HIGH or MEDIUM LOW setting for acceleration.

4.2 BLDC Motor using Analog Drive:

While running the BLDC motor in Sensorless Mode and using Analog Drive, make sure the Potentiometer (R50 on the Fusion Kit connected to AV0 or pin 'M6') is at its maximum (The LED's on Fusion Kit, D1 to D8 will reflect the value of the Potentiometer setting, the value will be Hex FA, D8- MSB and D1 - LSB)

In case of sensored drive, this Potentiometer can be at any position and the motor will start and run at the speed set by the Potentiometer.

4.3 Stepper Motor using Analog Drive:

In the case of Stepper there are only 16 steps for speed control. The 4 MSB bits of the analog ADC outputs as reflected by the LED's D4-D1 control the divide by N ratio of the applied frequency to the stepper drive circuit.

While running the stepper motor using Analog Drive, make sure the Potentiometer (R50 on the Fusion Kit connected to AV0 or pin 'M6') is at its maximum (The LED's on Fusion Kit, D4 to D1 will reflect the value of the Potentiometer setting)

4.4 Stepper Motor Anomalous Behavior:

When the RPM setting is at 'C' or 12 and the settings are "Full Step" and Range_Select is OFF, the Stepper motor stutters. This is due to the applied frequency matches to the resonance frequency of the motor based on the winding inductance and resistance. This is particular to the motor supplied with the kit and this behavior may not be seen with another motor configuration which has different inductance and resistance value for the windings.

4.5 Temperature and Current Sensing (If supported by the STP file):

These sensing results are not to be treated as accurate. This feature is just provided for sampling the current and temperature values at the switching instant. The sensors are not highly accurate and the tolerance of these sensors is very loose so the displayed results may vary.

For LCD display on Fusion

Press and hold switch 1- Current display

Press and hold switch 2- Temperature display

5. Board Description and Usage

5.1 Block Diagram

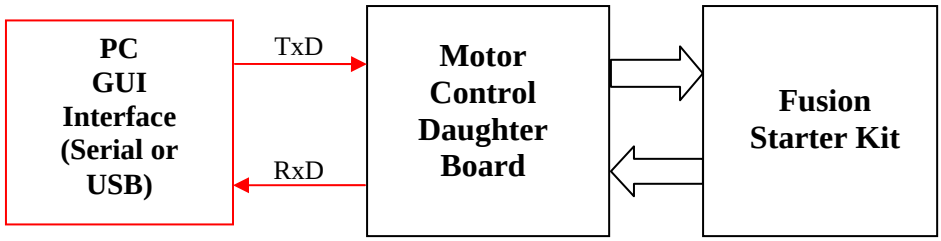


Figure 5.1.1 BLDC/Stepper Motor Controller

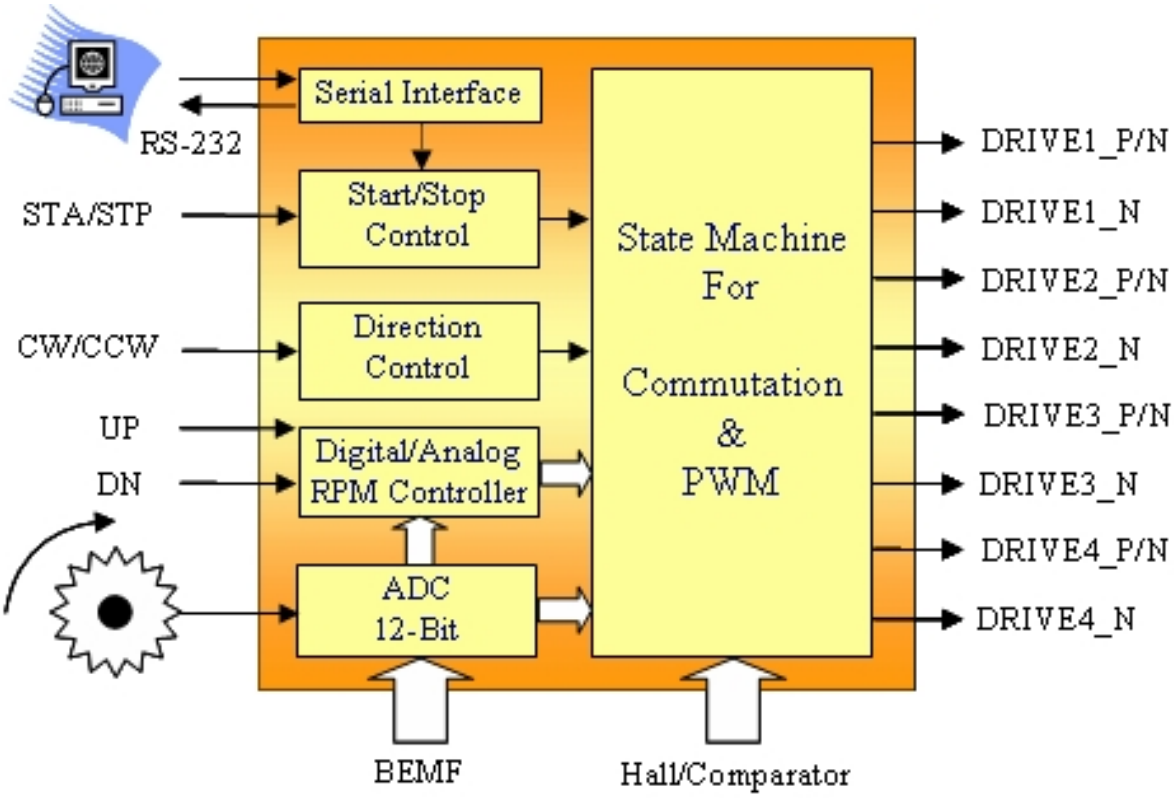


Figure 5.1.2 Fusion Motor Controller IP

5.2 Pictures

5.2.1 Motor Control Daughter Board

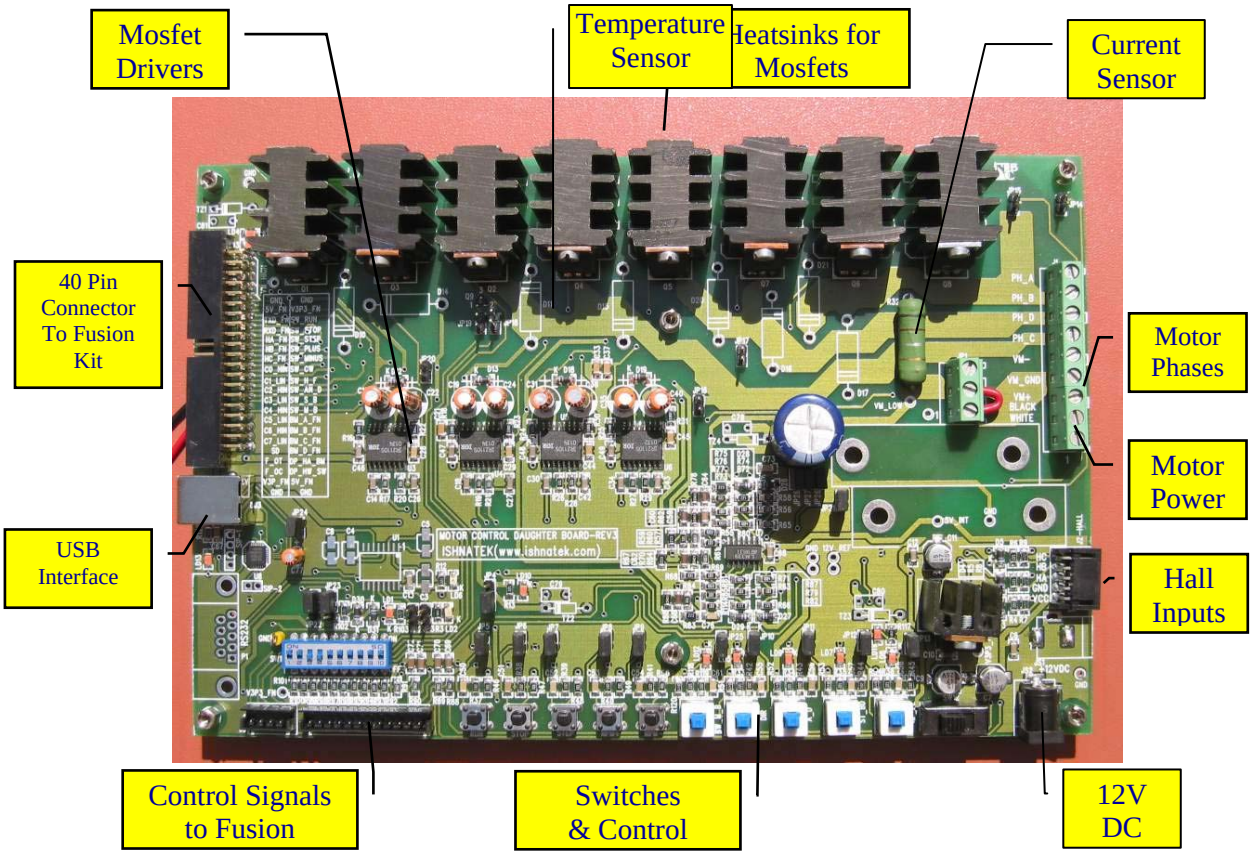


Figure 5.2.1 Motor Control Daughter Board

5.2.2 Motor Control Kit - Picture

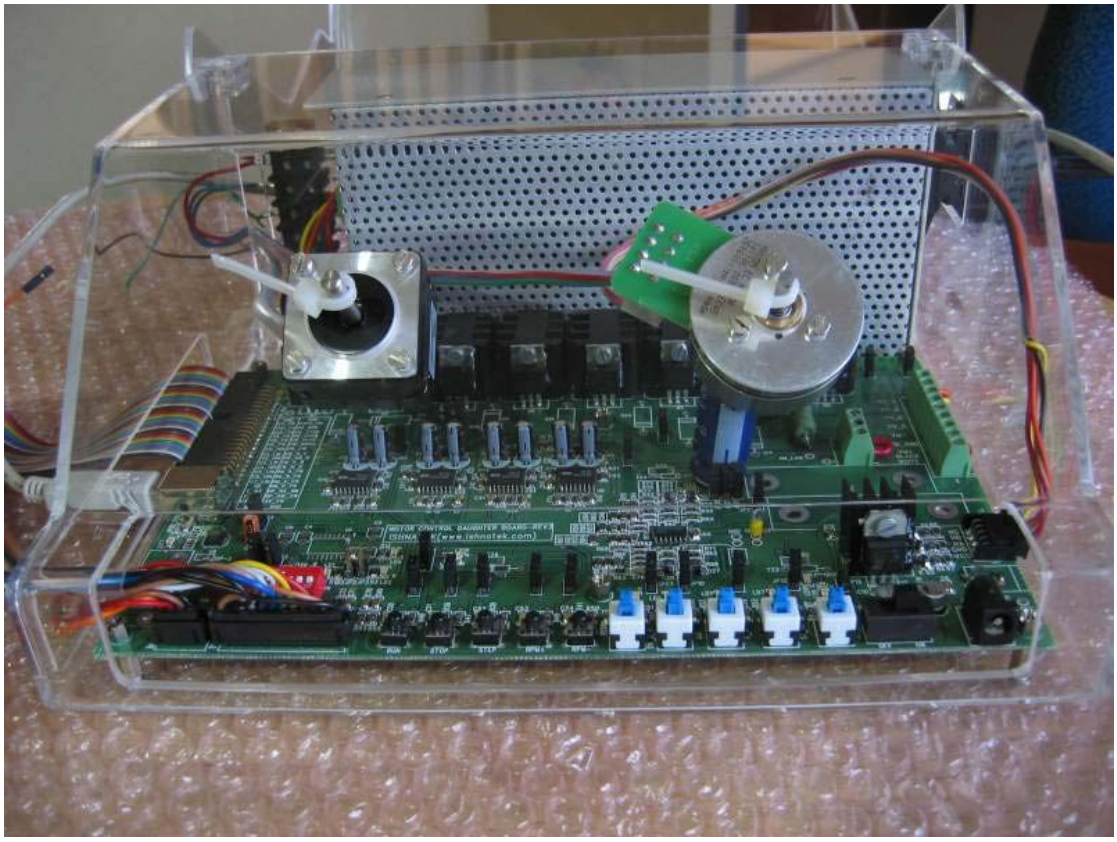


Figure 5.2.2 Motor Control Kit

5.*3 Status LED's*

LED	Function	Notes
LD1	RxD Indicator (RED)	Indicates serial reception in progress (Reserved)
LD2	TxD Indicator (YELLOW)	Indicates serial transmission in progress (Reserved)
LD3	Fault_OT Indicator (RED)	ON- Over-temperature fault condition detected OFF- Over temperature condition not detected
LD4	Fault_OC Indicator (RED)	ON- Over-current condition detected OFF- Over-current not detected The threshold for over-current will be determined by the shunt resistor and the flags generated out of the Analog Current Monitor in Smartgen.
LD5	DIR Indicator (RED) (When JP10 is closed)	ON – Motor will move in clockwise direction OFF – Motor will move in counterclockwise direction
LD6	5V_int Indicator (GREEN)	5V signal on Daughter Board Active JP4 (5V_int) 1-2 -> 5V_FN (5V from Fusion board) 2-3 -> 5V_REF (5V through on board regulator)
LD7	ST_BD Indicator (RED) (When JP12 is closed)	ON- Stepper motor selected OFF- BLDC motor selected
LD8	HF_FL Indicator (RED) Or Comp or ADC Indicator (When JP13 is closed)	In case of Stepper motor ON- Full-step mode OFF- Half -step mode In case of BLDC motor ON - BEMF drive using on board comparator OFF - BEMF drive using Fusion ADC
LD9	A_D Indicator (RED) (When JP11 is closed)	ON- Analog Control of RPM OFF- Digital Control of RPM During Analog Control Switches RPM+ and RPM- will have no effect on the RPM. The RPM is controlled using the potentiometer on pin AV0 of Fusion
LD10	5V_FN Indicator (RED)	5V from the Fusion board is chosen and active
LD11	12V_REF Indicator (RED)	12V Supply on the daughter board is active
LD12	SW_M_B Indicator (RED) (When JP25 is closed)	In case of Stepper motor ON- Microstepping ON OFF- Microstepping OFF In case of Brushed or Brushless motor ON - Brushed motor OFF - Brushless motor
LD13	USB 5V Indicator (RED)	USB cable is plugged in

5.4 Jumpers/Short Links

Jumper	Function	Notes
JP1	Link for low side polarity of motor power supply	1-2 -> GND connects to VM_Low 2-3 -> VM- connects to VM_Low
JP2	LED for Serial Reception	Close - Connects LED for serial reception Open - Disconnects LED for serial reception
JP3	LED for Serial Transmission	Close - Connects LED for serial transmission Open - Disconnects LED for serial transmission
JP4	Jumper to select 5V power to be used on Daughter Board.	1-2 -> Use 5V from Fusion Board 2-3 -> Use 5V from Daughter Board (IC7805 regulator)
JP5	'RUN' from the Daughter Board	Close – Connects Key 'RUN' from the daughter board Open - Disconnects Key 'RUN' from the daughter board When Open, user can use external keypad to control RUN signal/command to Fusion
JP6	'STOP' from the Daughter Board	Close – Connects Key 'STOP' from the daughter board Open - Disconnects Key 'STOP' from the daughter board When Open, user can use external keypad to control STOP signal/command to Fusion
JP7	'STEP' from the Daughter Board	Close – Connects Key 'STEP' from the daughter board Open - Disconnects Key 'STEP' from the daughter board When Open, user can use external keypad to control STEP signal/command to Fusion
JP8	'RPM+' from the Daughter Board	Close – Connects Key 'RPM+' from the daughter board Open - Disconnects Key 'RPM+' from the daughter board When Open, user can use external keypad to control RPM+ signal/command to Motherboard
JP9	'RPM-' from the Daughter Board	Close – Connects Key 'RPM-' from the daughter board Open - Disconnects Key 'RPM-' from the daughter board When Open, user can use external keypad to control RPM- signal/command to Fusion
JP10	'DIR' from the Daughter Board	Close – Connects Key 'DIR' from the daughter board Open - Disconnects Key 'DIR' from the daughter board When Open, user can use external keypad to

		control DIR signal/command to Fusion
JP11	'A_D' from the Daughter Board	Close – Connects Key 'A_D' from the Daughter Board Open - Disconnects Key 'A_D' from the Daughter Board When Open, user can use external keypad to control A_D signal/command to Fusion
JP12	'ST_BD' from the Daughter Board	Close – Connects Key 'ST_BD' from the daughter board Open - Disconnects Key 'ST_BD' from the daughter board When Open, user can use external keypad to control ST_BD signal/command to Fusion
JP13	'HF_FL' from the Daughter Board	Close – Connects Key 'HF_FL' from the daughter board Open - Disconnects Key 'HF_FL' from the daughter board Use external keypad to control HF_FL signal/command to Motherboard
JP14	Snubber Circuit for MOT_A direct feedback Signal	These signals are used to drive BLDC motor using Fusion's onboard ADC. Fusion's ADC generates threshold flags, which are then used to commutate the motor. These are scaled down voltages through a resistor divider network. Connect MOT_A to M9, MOT_B to N7, MOT_C to N9 if, IP supports this mode.
JP15	Snubber Circuit for MOT_B direct feedback Signal	
JP16	Snubber Circuit for MOT_C direct feedback Signal	
JP17	Snubber Circuit for MOT_D direct feedback Signal	
JP18	TSIG Signal for Temperature Sensing	Close – Connects 'TSIG' from the daughter board Open - Disconnects 'TSIG' from the daughter board
JP19	TRTN Signal for Temperature Sensing	Close – Connects 'TRTN' from the daughter board Open - Disconnects 'TRTN' from the daughter board
JP20	VM_CS signal for Current Sensing	Close – Connects 'VM_CS' from the daughter board Open - Disconnects 'VM_CS' from the daughter board
JP21	VM_LOW signal for Current Sensing	Close – Connects 'VM_LOW' from the daughter board Open - Disconnects 'VM_LOW' from the daughter board
JP22	Selects data reception from	1-2 – CP2103 (USB to Serial Chip)

	MAX232 or CP2103	2-3 – MAX232 (RS232 Interface Chip)
JP23	Selects data transmission from MAX232 or CP2103	1-2 – CP2103 (USB to Serial Chip) 2-3 – MAX232 (RS232 Interface Chip)
JP24	Configure the IO's of CP2103	Close (default) – Configure the IO's of CP2103 to 3.3V Open - Configure the IO's of CP2103 to 1.8V
JP25	'SW_M_B' from the Daughter Board	Close – Connects Key 'SW_M_B' from the daughter board Open - Disconnects Key 'SW_M_B' from the daughter board Use external keypad to control SW_M_B signal/command to Fusion
JP26, JP27, JP28	Disconnects Motor ground from board ground.	Close – Connects motor power supply ground to the reference board's ground Open - Disconnects motor power supply ground from the reference board's ground (3 Jumpers are provided for stronger ground)
SIP-1, SIP-2	RESERVED	Reserved for internal use, keep Open

5.5 Switches

Switches	Function		Notes
SW12	Daughter board power supply 12V, 2A (Connect to Dual Supply (12V/2A Tap if provided))		12V Ref Voltage ON-OFF slide switch
RUN	Press 'RUN' to start the motor		Push to ON tactile switch
STOP	Press 'STOP' to stop the motor		Push to ON tactile switch
STEP	Press 'STEP' to single step the stepper motor. *Note: The step size is chosen based on the position of the 'HF_FL' toggle switch*		Push to ON tactile switch
RPM+	Press RPM+ to increase speed of motor		Push to ON tactile switch
RPM-	Press RPM- to decrease speed of motor		Push to ON tactile switch
SW_M_B	ST_BD- ON (Stepper)	ON- Microstepping ON OFF- Microstepping OFF	Toggle tactile switch
	ST_BD- OFF (Brushed / Brushless)	ON- Brushed motor OFF- Brushless motor	
DIR	Motor rotation direction ON- Clockwise OFF - Counterclockwise		Toggle tactile switch
A_D	Motor Control Type ON- Analog (POT) OFF – Digital (RPM+ and RPM- switches)		Toggle tactile switch
ST_BD	Motor Type ON – Stepper OFF – Brushed or Brushless		Toggle tactile switch
HF_FL	ST_BD- ON (Stepper) & SW_M_B- OFF	ON- Full Step (1.8 degrees) OFF- Half Step (0.9 degrees)	Toggle tactile switch
	ST_BD- OFF (Brushed / Brushless) & SW_M_B- OFF (BLDC motor)	ON- BEMF drive using on board comparator OFF- BEMF drive using Fusion's onboard ADC	
SW10	[10:9] ST_BD- OFF (Brushed / Brushless)	PWM_FR_SEL[1:0] 00– 39 KHz 01– 78 KHz 10– 156 KHz 11– 312 KHz	10-Way dip switch

	[8:7]	ST_BD- ON (Stepper) & SW_M_B-ON	NO_OF_MICROSTEP [1:0] 00– 8 Steps 01– 16 Steps 10– 32 Steps 11– Reserved	
		ST_BD- OFF (Brushed / Brushless) & SW_M_B-OFF (BLDC)	BLDC_MODE [1:0] 00–Complementary PWM 01– High Side PWM 10– Low Side PWM 11– Both Sides PWM	
	[6:5]	ST_BD- OFF (Brushed / Brushless) & SW_M_B-OFF (BLDC)	ACCEL_TIME [1:0] 00– 206 milliseconds 01– 312 milliseconds 10– 520 milliseconds 11– 3.74 Seconds	
	4	ST_BD- ON (Stepper) & SW_M_B-OFF	RANGE_SEL_STEPPER ON – High RPM Range OFF – Low RPM Range	
	3	ST_BD- ON (Stepper) & SW_M_B-ON	MICROSTEP_TZ_SINE ON- Microstep in Trapezoidal form OFF-Microstep in sine form	
		ST_BD- OFF (Brushed / Brushless)	PWM_ON_OFF ON - PWM ON OFF – PWM OFF	
	2	ST_BD- OFF (Brushed / Brushless) & SW_M_B-OFF (BLDC)	HALL_OR_BEMF ON – HALL Sensor OFF – BEMF Control	
	1		HW_SW ON- Hardware Control OFF– Software Control	

5.6 Connectors

Connector Type	Description	Notes
JS1 & JS2 -Power	12V Power Connector Round PTH type 3-pin barrel connector	12V, 2A power supply for reference board
J1	Stepper / BLDC / Brushed Motor Connections 9-Pin Phoenix Terminal Connector 3-Pins(VM+, VM_GND, VM-) for Motor Power Supply 2-Pins (WHITE and BLACK) for 6-wire stepper motor) 4- Pins (PH_A, PH_B, PH_C, PH_D – Motor Phases)	1 – WHITE 2 – BLACK 3 – VM+ 4 – VM_GND 5 – VM- 6 – PH_C 7 – PH_D 8 – PH_B 9 – PH_A
J2-Hall	5-Pin Connector for Hall sensor feedback from Motor	1 – VCC 2 – GND 3 – HA 4 – HB 5 – HC
J3	USB connector for serial interface	
J4	40-Pin Bus Connector from Daughter Board to Fusion Motherboard	May need to make a cut in the header to accommodate this cable on Fusion side
J5	12-Pin Straight Connector	1 – SW10 – 3 2 – SW10 – 4 3 – SW10 -5 4 – SW10 -6 5 – SW10 – 7 6 – SW10 – 8 7 – SW10 – 9 8 – SW10 – 10 9 – MOT_D *Scaled BEMF D* 10 – MOT_C *Scaled BEMF C* 11 – MOT_B *Scaled BEMF B* 12 – MOT_A *Scaled BEMF A*
J6	4-Pin Straight Connector	Other Control / Status / Feedback Signals to Fusion 1 – T_RTN

		(temperature sense return) 2 – T_SIG (temperature sense signal) 3 – VM_CS_OUT (current sense out) 4-VM_LOW_OUT (voltage sense out)
RS232	Serial Interface Connector *(Optional if USB Connector not provided)*	Only RxD, TxD and GND used

6. Detailed Design Description

6.1 Stepper Motor

A Stepper Motor would require four push-pull drivers to commutate. The stepper motor requires a fixed sequence of phase voltages the motor windings must be supplied with for proper commutation. For a 4-wire/6-wire motor there are 2 windings provided. One winding is powered while the current in the other winding is gradually dropped to zero, reversed and then ramped up again. The sequence and period will define the speed of commutation.

In the case of 6-wire Stepper Motor (Figure 4.1), 2 additional wires are provided. A center tap from each of the windings is brought out externally. A high wattage resistor is required on board to dissipate the power in the windings. Refer to motor specifications for exact values of R_{ext} to be used.

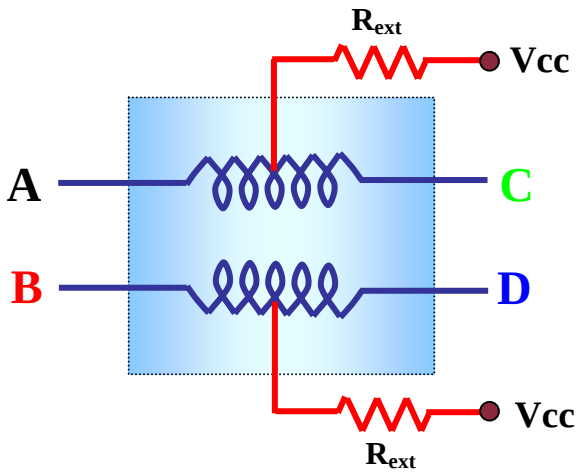


Figure 6.1 4-Wire/6-Wire 2 Phase Stepper Configuration

In the case of 4-wire or 6-wire Stepper motor, four vectored inputs are used to directly control which switches are open or closed in the push-pull stage. In some motors the inputs may be encoded while others may control subsystems such as the analog to digital converter in a microstepping interface.

A control vector is defined as the state of each logic input and control trajectory is defined by the sequence of states used to commutate the rotor. The control trajectory remains the same for both types of motors

Note: There could be different control trajectory for different motor designs, please make the design changes accordingly to conform to motor specification.

The control vectors required for microstepped motors are more complex, but the basic idea remains the same. Higher level control system is designed that will generate appropriate control trajectories, moving the motor one step, half-step or microstep.

6.1.1 Stepper Drive

6.1.1.1 Full-Step Mode:

In this case the motor commutates 1.8 mechanical degrees. The motor would require 200 such full-steps for one mechanical revolution of the rotor.

The control trajectory for stepping though one full electrical cycle using full stepping is as follows:

Sequence	A	C	B	D
1	1	0	1	0
2	1	0	0	1
3	0	1	0	1
4	0	1	1	0

Clockwise

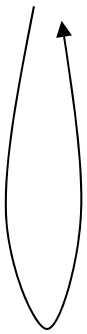
Table 6.1.1.1 Full-Step Stepper Motor Sequence

6.1.1.2 Half-Step Mode:

In this case the motor commutates 0.9 mechanical degrees every step. The motor would require 400 such half-steps for one mechanical revolution.

The control trajectory for stepping though one full electrical cycle using half stepping is as follows:

Sequence	A	C	B	D
1	1	0	1	0
2	1	0	0	0
3	1	0	0	1
4	0	0	0	1
5	0	1	0	1
6	0	1	0	0
7	0	1	1	0
8	0	0	1	0



Clockwise

Table 6.1.1.2 Full-Step Stepper Motor Sequence

6.1.1.3 Micro-Step Mode:

Micro-stepping can be done in trapezoidal form or sine form with 8, 16 or 32 steps. Micro-steps mean fraction of full step (1/8, 1/16 or 1/32). The step rate has to be increased by a corresponding factor (8, 16, or 32) for same rpm. Pulse Width Modulation (PWM) technique is used to implement Micro-step mode, by varying the duty cycle of the applied voltage.

Step No.	Dutycycle Value 32 Steps		Dutycycle Value 16 Steps		Dutycycle Value 8 Steps	
	Value	%	Value	%	Value	%
1	05	2	05	2	05	2
2	1B	11	31	19	61	38
3	31	19	61	38	B4	63
4	4A	29	8C	55	EB	92
5	61	38	B4	63	EB	92
6	78	47	D4	83	B4	63
7	8C	55	EB	92	61	38
8	A0	63	FA	98	05	2
9	B4	70	FA	98		
10	C6	77	EB	92		
11	D4	83	D4	83		
12	E0	88	B4	63		
13	EB	92	8C	55		
14	F4	95	61	38		
15	FA	98	31	19		
16	FE	100	05	2		
17	FE	100				
18	FA	98				
19	F4	95				
20	EB	92				
21	E0	88				
22	D4	83				
23	C6	77				
24	B4	70				
25	A0	63				
26	8C	55				
27	78	47				
28	61	38				
29	4A	29				
30	31	19				
31	1B	11				
32	05	2				

Table 6.1.1.3. Duty Cycles for 32 /16 /8 Microstep options

6.1.1.3.1 Sinusoidal Microstepping Method:

In this mode the Stepper commutation sequence is applied as shown below.

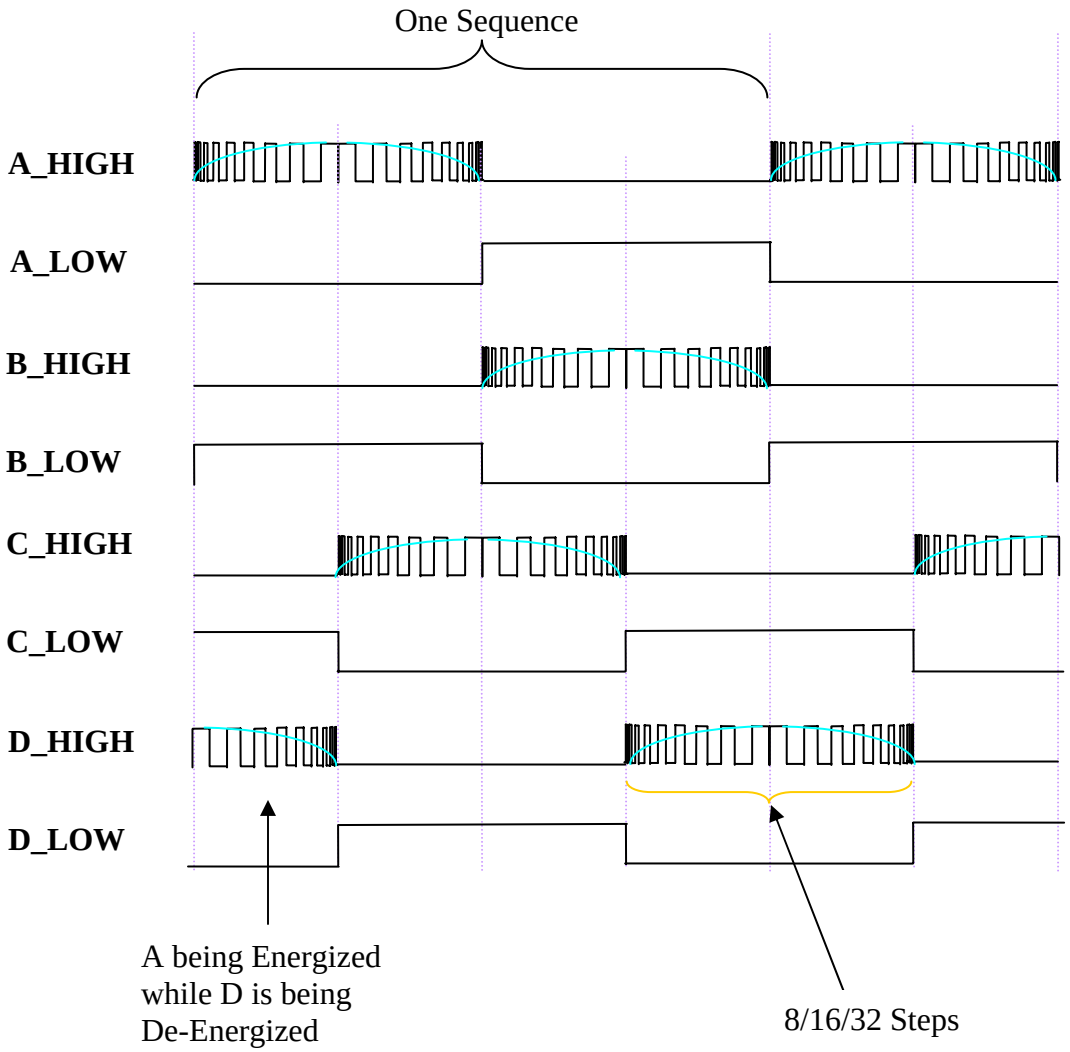


Figure 6.1.1.3.1 Sinusoidal Microstepping Method

PWM frequency during Microstepping (Both Sinusoidal and Trapezoidal) is generated as follows:

PWM Frequency = ((NO_OF_STEPS/2)) * ((4881 Hz) / (DIV_BY_N + 1))

For e.g DIV_BY_N = 6, , NO_OF_STEPS = 32,
The PWM Frequency would be : 11.158 KHz
The PWM Generator Frequency is : 11.158 KHz X 256 i.e. 2.85 MHz

6.1.1.3.2 Trapezoidal Microstepping Method:

In this mode the Stepper commutation sequence is applied as shown below.

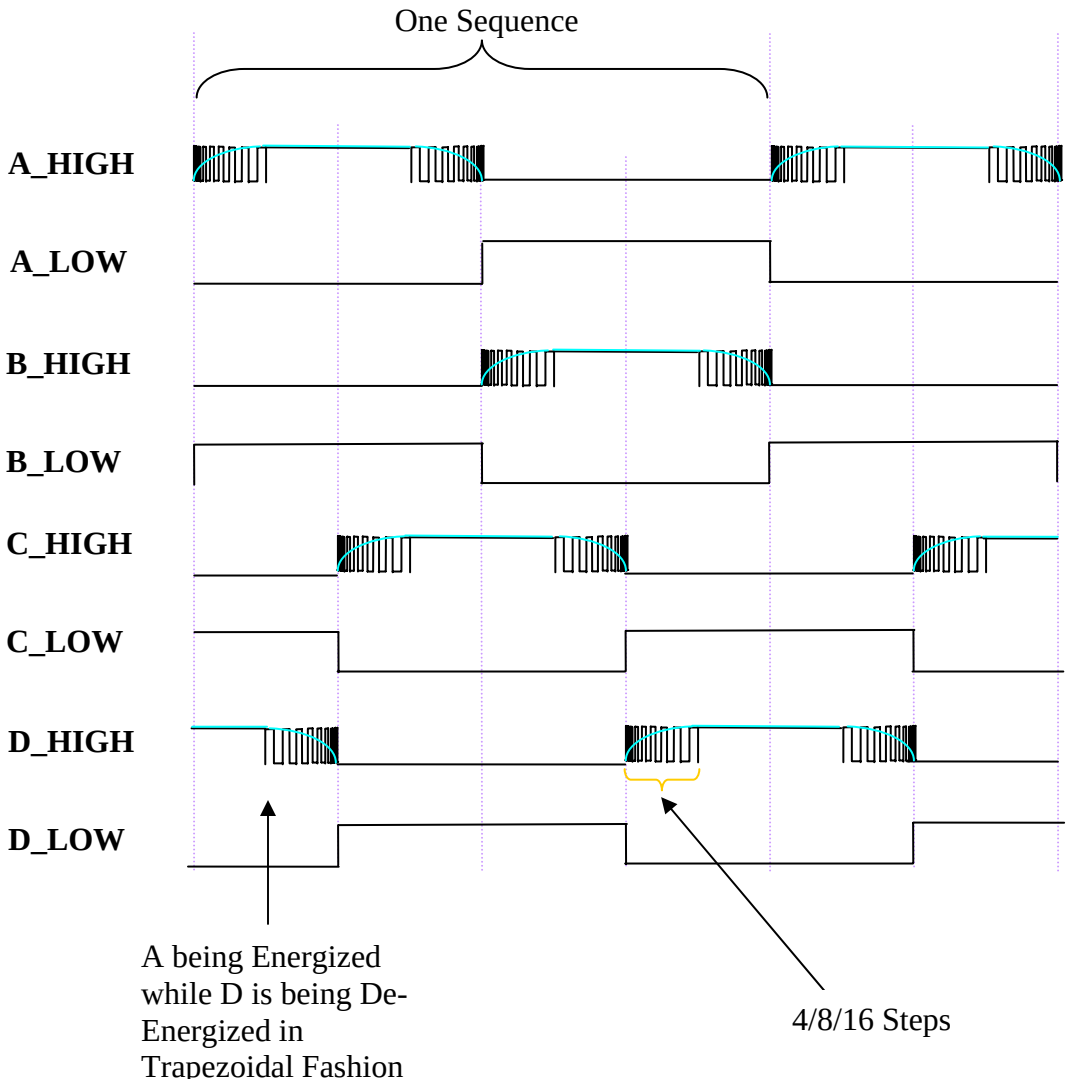


Figure 6.1.1.3.2 Trapezoidal Microstepping Method

6.1.2 STEPPER motor control state machine

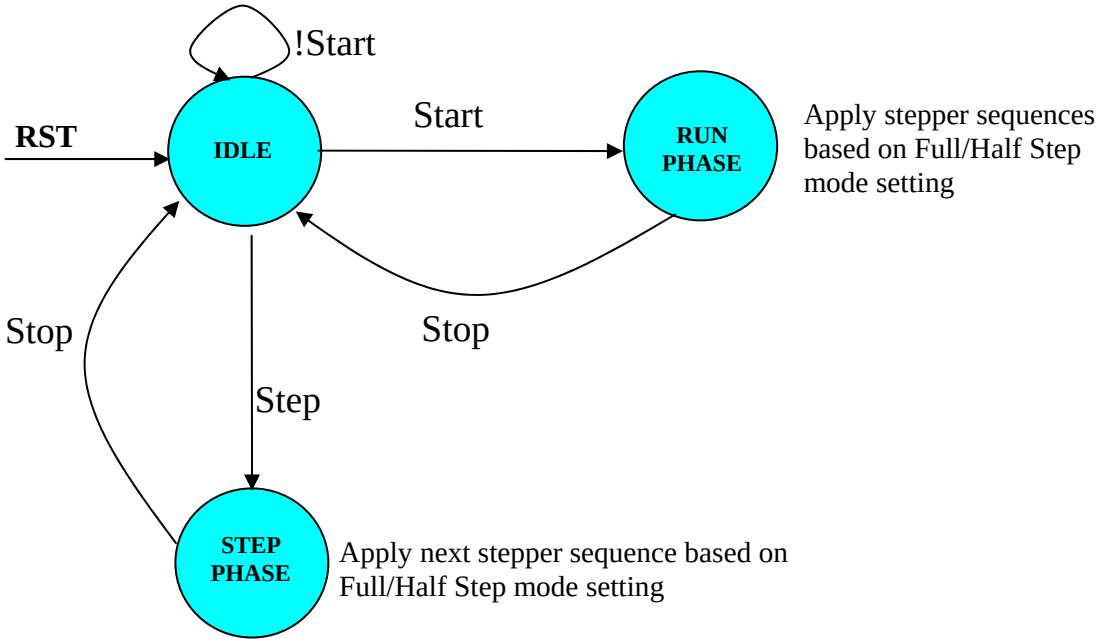


Figure 6.1.2. Stepper motor control state machine

6.1.3 Stepper motor speed calculation

FULL STEP:

If range select switch is ON

Speed in rpm = (9764/((div_by_N+1)*200))*60

If range select switch is OFF

Speed in rpm = (4882/((div_by_N+1)*200))*60

HALF STEP:

If range select switch is ON

Speed in rpm = (9764/((div_by_N+1)*400))*60

If range select switch is OFF

Speed in rpm = (4882/((div_by_N+1)*400))*60

6.2 BLDC Drive

A BLDC Motor is a synchronous motor with no damping or starting windings. Three logic signals are decoded to determine the next winding sequence.
A Three Phase Motor requires three push-pull stages. In each of the six possible states two outputs are active at a given time (current flows in only two windings of the stator). Each state translates to electrical sectors.

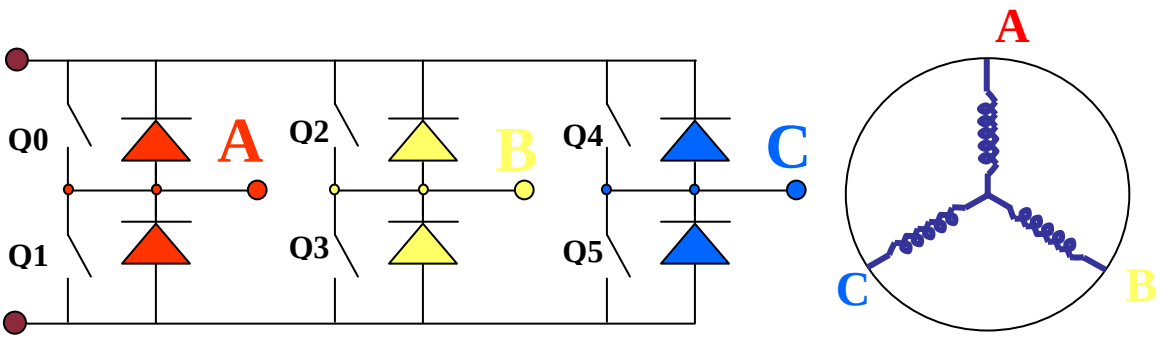


Figure 6.2 Push-Pull stages of a 3-phase bldc drive

Simple Control Technique would be to sense the change in the state of the position of the rotor and apply the next step/state for commutation. In case sensors are provided, the position is known by reading the Hall sensors to determine the next state. Pulse Width Modultation (PWM) is used for speed control.

6.2.1 Sensored Drive - Hall Effect Sensors

Motor is commutated based on the signals given by the Hall Sensors mounted at various positions inside the motor. Hall outputs change very 60 electrical degrees. The state of the control switches and the Hall sensor signals are scanned continuously. A new voltage vector / control trajectory is applied to the BLDC Motor based on the Hall sensor signal conditions. This mechanism is known as commutation.

The Hall position sensors sense the actual rotor position. The hall outputs are monitored by the controller and appropriate commutation sequence is applied to assist in commutating the motor. The speed of the motor is varied by making use of PWM outputs on the output voltages. Typically there are three hall effect sensors provided inside the motor. The three sensors comprise of six states namely 001, 010, 011, 100, 101 and 110. Six steps are required to perform one complete electrical cycle. The electrical to mechanical ratio is based on the pole pairs inside the motor. Each state corresponds to the actual rotor position inside the motor. This determines the required direction of voltage vector based on the direction in which the rotor needs to be moved. A vector table is generated for the sensor state and the next commutation sequence. The Hall sensors require an external power supply.

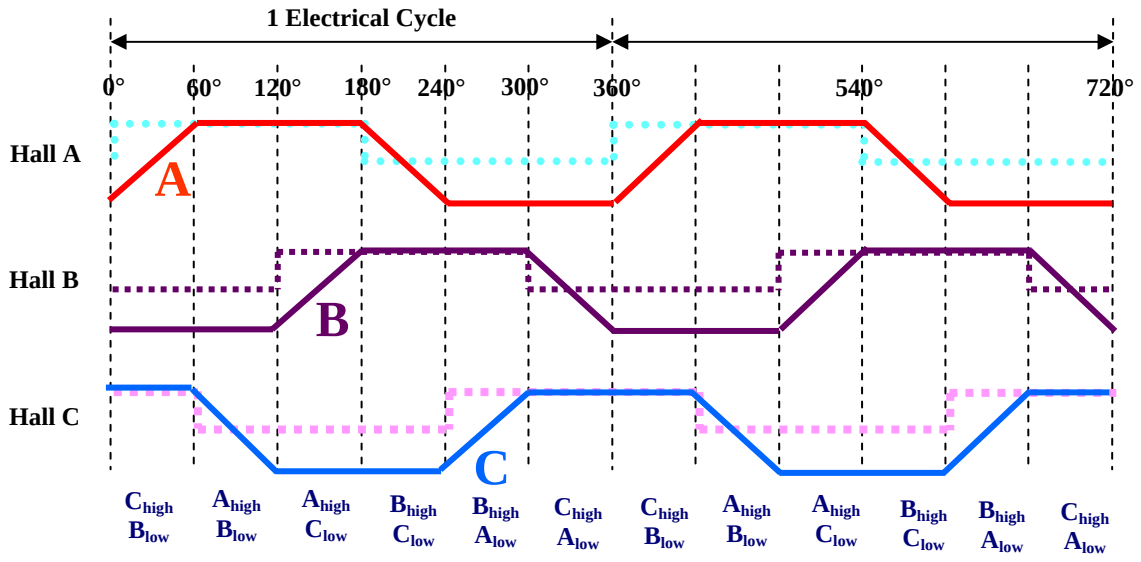


Figure 6.2.1.1 Commutation using Hall sensors

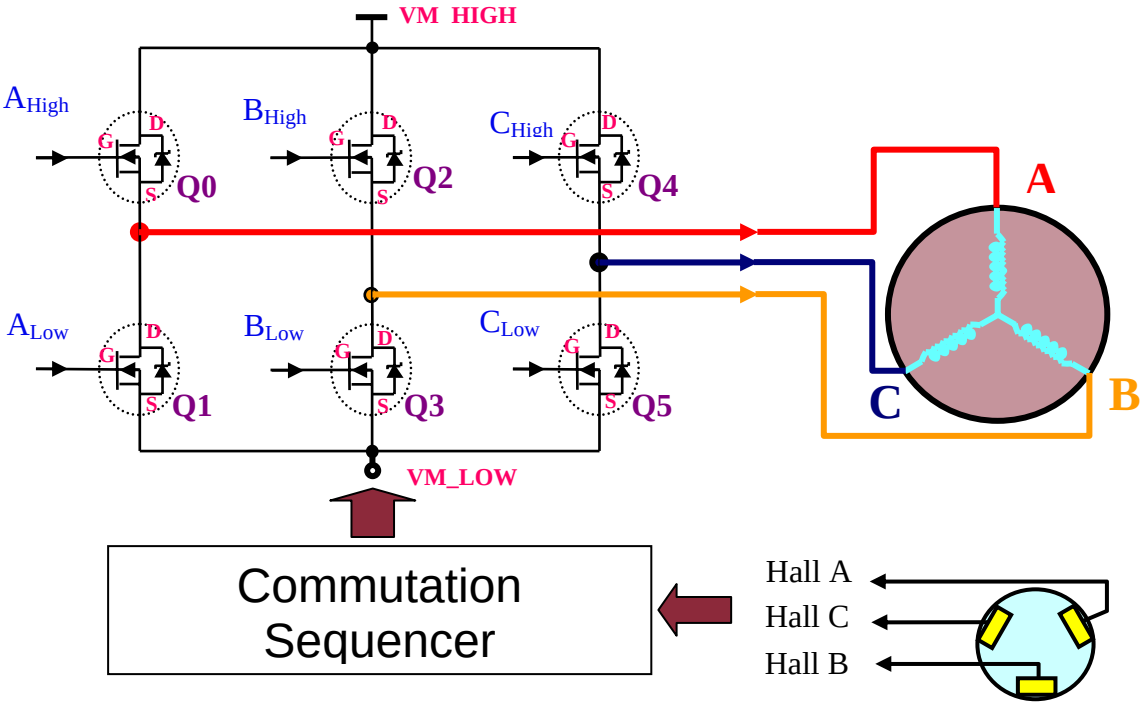


Figure 6.2.1.2 Mosfet bridge circuit for commutation

6.2.2 Sensorless Drive - *BEMF Sensing*

In case of a BLDC motor, each stator winding generates a Back Electromotive Force. The rotor position is inferred based on the induced voltage on the inactive winding. The Zero-Crossing of the BEMF is a significant point for commutation.

Back EMF is proportional to the angular velocity of the rotor, magnetic field generated by rotor magnets and the number of turns of stator windings. Current has to be commutated in phase with BEMF to get optimal control and maximum torque per current

Startup: On start command the rotor is first aligned to a known position in DC excitation mode. At low speeds BEMF is low hence zero-crossing detection becomes difficult hence the motor is started in a forced commutation mode (this can also be referred to as open-loop mode). As BEMF is a function of rotor rpm the BEMF is initially zero when the rotor is still. So measurable BEMF should be generated to be able to self commutate (close-loop mode). When a sufficient BEMF is generated we can shift to auto commutation.

In every commutation (Three phase) step, one winding is positive, one winding negative and the third is floating. The back-EMF zero crossing detection enables position recognition. Detect zero-crossing of BEMF for the winding that is floating in order to commutate to next step/sequence. A resistor network is used to step down sensed voltages to a 0–5 V level. Zero crossing detection is done using external comparators by synthesizing a Star reference point (Neutral point of the motor is unavailable)

At slower frequencies in forced commutation mode the current consumption is very high. Hence the motor is brought to auto commute mode by accelerating quickly to the rpm where BEMF is above the threshold. The acceleration times are variable through the switches provided on board for experimenting with this phenomenon.

Acceleration Settings:

The IP supports four different acceleration time settings

- Fast (206 milliseconds)
- Medium low (312 milliseconds)
- Medium high (520 milliseconds)
- Slow (3.74 seconds)

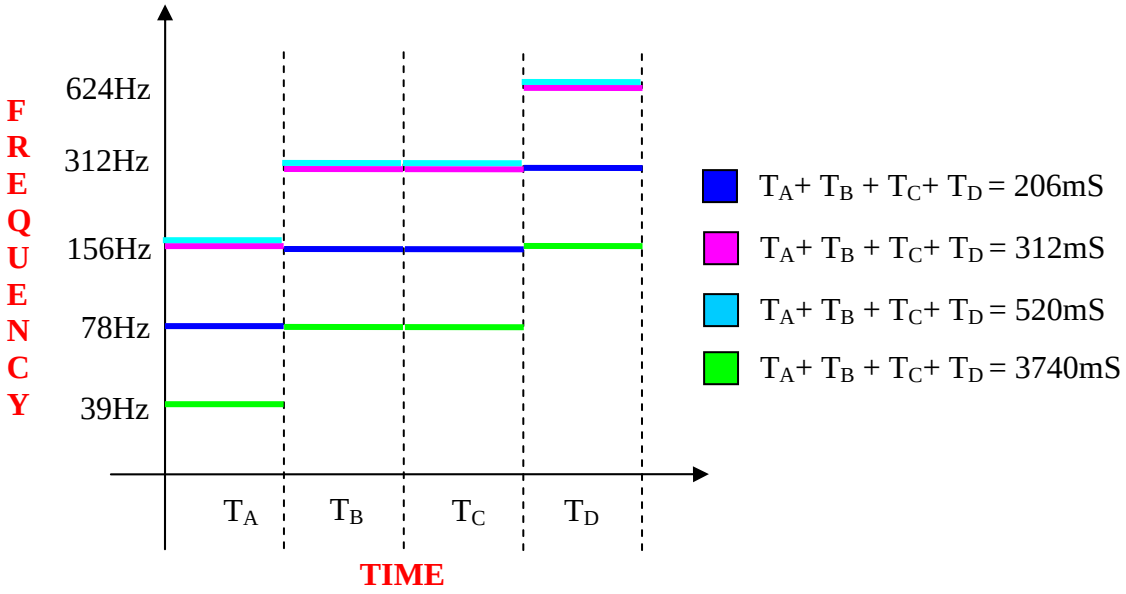


Figure 6.2.2. Acceleration timings

The forced commutation frequency for startup operations depend very much on the motor type and loading. Most of the times this will be adjusted only experimentally.

6.2.3 PWM Frequency

The PWM frequency can be variable for running different motor types. Typically the PWM frequency must be much higher (approx 10X) than the electrical frequency of the motor and below the threshold frequency of the switching mosfets (< 100 KHz).

PWM Frequency = PWM_GEN_FREQUENCY / 256

There are 4 different options for PWM_GEN_FREQUENCY provided in hardware and software.

PWM_FR_SEL[1:0]	PWM_GEN_FREQUENCY
00	39 KHz
01	78 KHz
10	156 KHz
11	312 KHz

6.2.4 Speed Control

The speed of the motor is directly proportional to the applied voltage. By varying the average voltage across the windings the rpm can be altered. This is achieved by altering the duty cycle of the base PWM signal. Maximum speed is achieved when PWM is OFF. In that case the mosfets are ON 100% of the commutation period. When PWM is turned ON then the speed is proportional to the duty cycle setting. The duty cycle modification can be done through Analog or Digital mechanism.

Analog Control of RPM:
An external potentiometer and the Fusion's internal 8/10/12-Bit ADC is used to alter the Duty Cycle of the base PWM base clock. The 8-bit Duty cycle value is fed to the design to adjust the duty cycle and hence control the speed of the motor.

Digital Control of RPM:
A fixed internal 8-bit register is incremented or decremented upon receiving the RPM+ or RPM- commands from the switches onboard or through the software interface. This alters the duty cycle and hence the speed of the motor.

6.2.5 Fault Protection

Over Current Protection:
A very small valued shunt resistor (10 milliohm) is put in series of the low side of the bridge and the negative terminal of the Motor Power supply. These two signals are fed to Fusion's analog quads to measure the current from the Motor's power supply using Potential differential method. A threshold current flag is generated from Fusion which could cause the Shutdown pin of the Mosfet driver to go active and switch off the

Mosfets. The Shutdown pin of the Mosfet driver is currently tied to OFF position. If you wish to use this feature you will need access to the code and do the alterations.

Over Temperature Protection:
A junction temperature of the transistor is used to measure the temperature in the vicinity of the Mosfets. If the Mosfets are running hot then the Fusion's Analog Quad block dedicated for temperature sensing would raise the threshold flag to indicate over temperature. A threshold temperature flag is generated from Fusion which could cause the Shutdown pin of the Mosfet driver to go active and switch off the Mosfets. The Shutdown pin of the Mosfet driver is currently tied to OFF position. If you wish to use this feature you will need access to the code and do the alterations.

6.2.6 Commutation

Typical 3-Ph Current Waveforms:

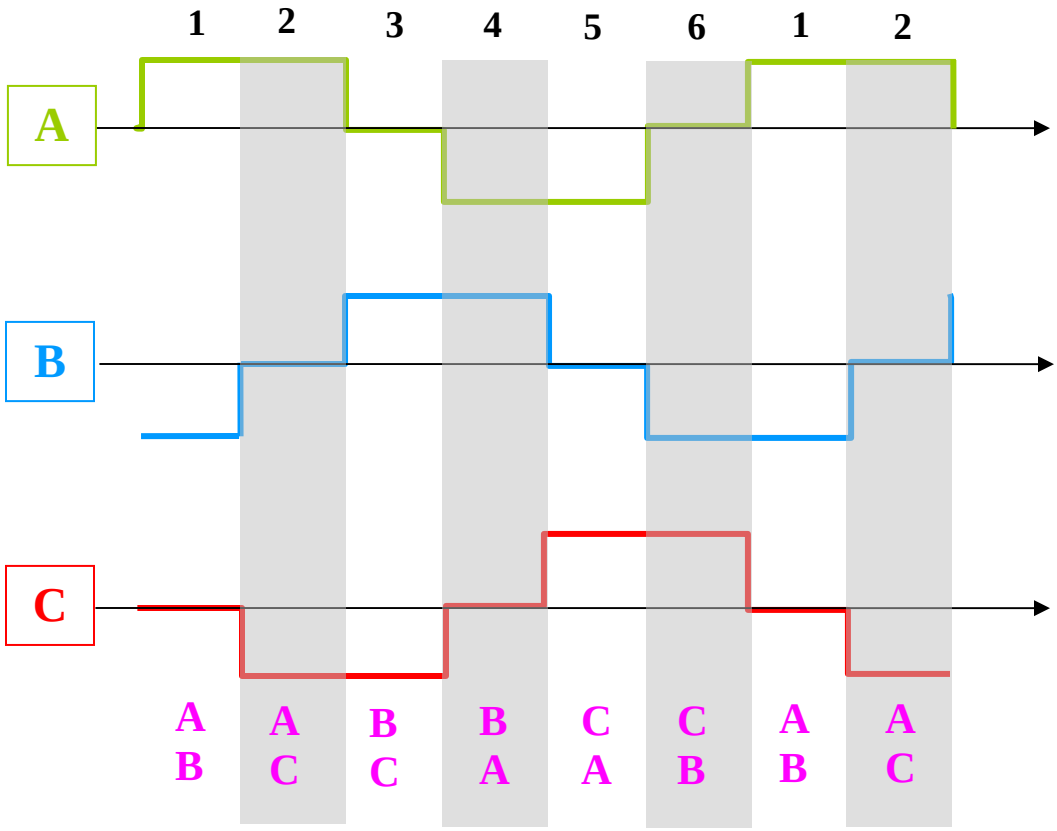


Figure 6.2.6 Six Step Commutation Waveform

Figure 4 shows the commutation sequence for a typical 3-Ph BLDC Motor. Each phase is active for 120 electrical degrees. At any given time/step interval notice that only two phases are active, the third phase is inactive or floating. This mechanism has built in dead time and assures that the two Mosfets in the same bridge are not active at the same time.

The commutation sequence as shown above will be AB-AC-BC-BA-CA-CB-AB-AC… and repeats there on. Notice that during AB sequence, the upper side of the A bridge is active while the lower side of B bridge is active. So current flows from DC+ through A high side to motor winding across A and B, passes through low side of B bridge and to DC-. Similarly for all other phases. The commutation timing is determined based on the position of the rotor. In case of Sensored drive, Hall effect sensor digital outputs determine the position of the rotor which can be used to move to the next logical sequence. In case of Sensorless drive, the BEMF on the floating winding is used to detect the rotor position and move to the next logical sequence to commutate the motor.

6.2.7 PWM Modes

- The average phase voltage is modulated to control the speed of the motor.
- Higher the average Voltage higher the RPM
- This can be achieved using PWM logic
- A Simple 8-Bit PWM Block is used
  - Duty Cycle
    - Digital Control –Internal 8-Bit Duty Cycle counter Incremented or decremented using RPM+ and RPM- keys on board
    - Analog Control – Potentiometer setting selects the 8-bit Duty Cycle value Period Counter
  - Period Counter
    - The PWM frequencies can be made variable based on motor specifications

6.2.7.1 PWM to High Side

In this case the PWM signal is applied only to the high-side of the Mosfet Pair. While the low side is driven 100% of the commutation period.

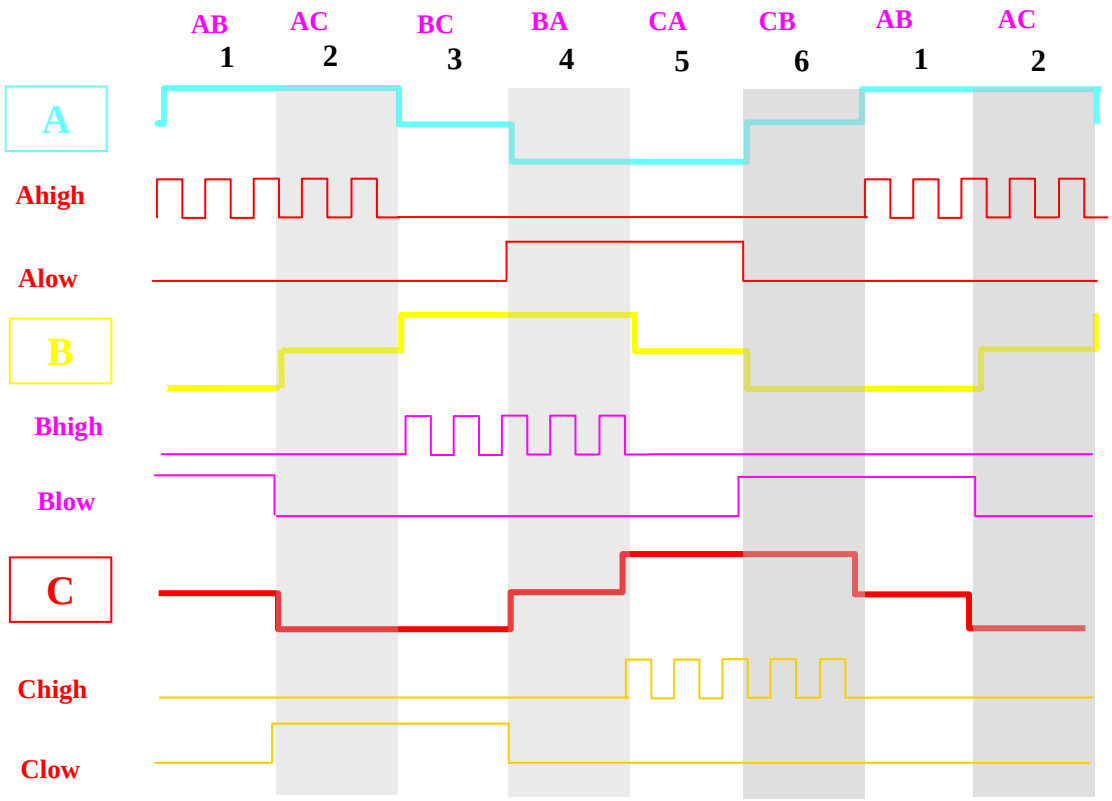


Figure 6.2.7.1 PWM to high side

Phase	PhaseA_H	PhaseA_L	PhaseB_H	PhaseB_L	PhaseC_H	PhaseC_L
Phase1	PWM	0	0	1	0	0
Phase2	0	0	0	1	PWM	0
Phase3	0	1	0	0	PWM	0
Phase4	0	1	PWM	0	0	0
Phase5	0	0	PWM	0	0	1
Phase6	PWM	0	0	0	0	1

Table 6.2.7.1. Phase sequence when PWM to high side

6.2.7.2 PWM to Low Side

In this mode, the PWM signal is applied only to the low-side of the Mosfet Pair. While the high-side is driven 100% of the commutation period.

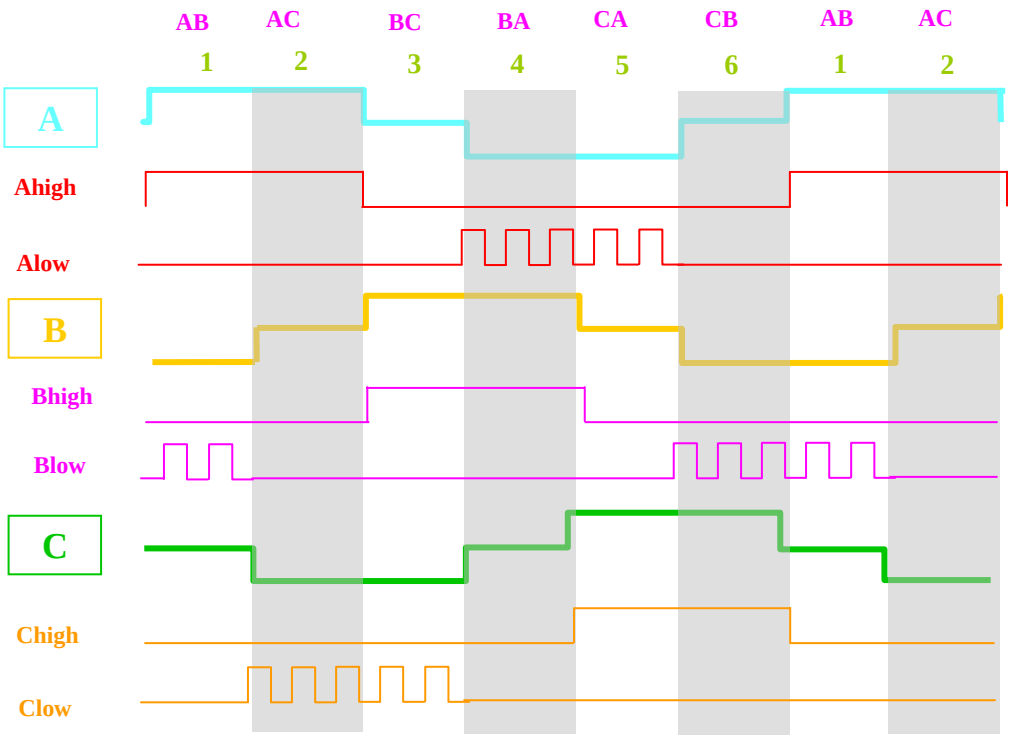


Figure 6.2.7.2 PWM to low side

Phase	PhaseA_H	PhaseA_L	PhaseB_H	PhaseB_L	PhaseC_H	PhaseC_L
Phase1	1	0	0	PWM	0	0
Phase2	0	0	0	PWM	1	0
Phase3	0	PWM	0	0	1	0
Phase4	0	PWM	1	0	0	0
Phase5	0	0	1	0	0	PWM
Phase6	1	0	0	0	0	PWM

Table 6.2.7.2. Phase sequence when PWM to low side

6.2.7.3 PWM to Both Sides

In this mode the PWM signal is applied to both sides of the Mosfet Pair. Care is taken in the design to ensure that there is enough dead time between the two signals in the Mosfet bridge and avoid any short circuit current.

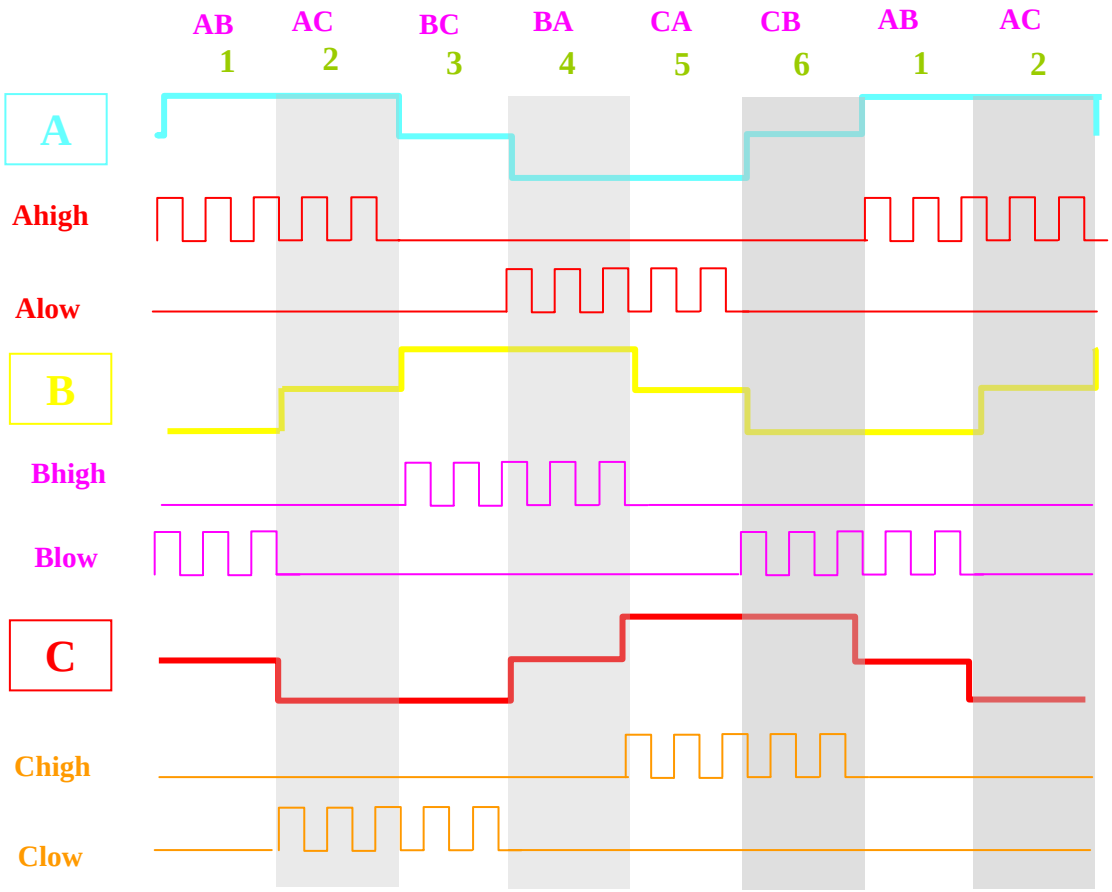


Figure 6.2.7.3 PWM to low side

Phase	PhaseA_H	PhaseA_L	PhaseB_H	PhaseB_L	PhaseC_H	PhaseC_L
Phase1	PWM	0	0	PWM	0	0
Phase2	0	0	0	PWM	PWM	0
Phase3	0	PWM	0	0	PWM	0
Phase4	0	PWM	PWM	0	0	0
Phase5	0	0	PWM	0	0	PWM
Phase6	PWM	0	0	0	0	PWM

Table 6.2.7.3. Phase sequence when PWM to both sides

6.2.7.4 Complementary PWM

In this case the PWM signal is applied in a complementary fashion to the high and low side of the bridge simultaneously. The freewheeling current flows through the mosfet instead of the body diode. This technique gives improved BEMF for low speed applications. The offset voltage caused by body diode is eliminated. Controller design to assure safe dead times in order to prevent short-circuit currents.

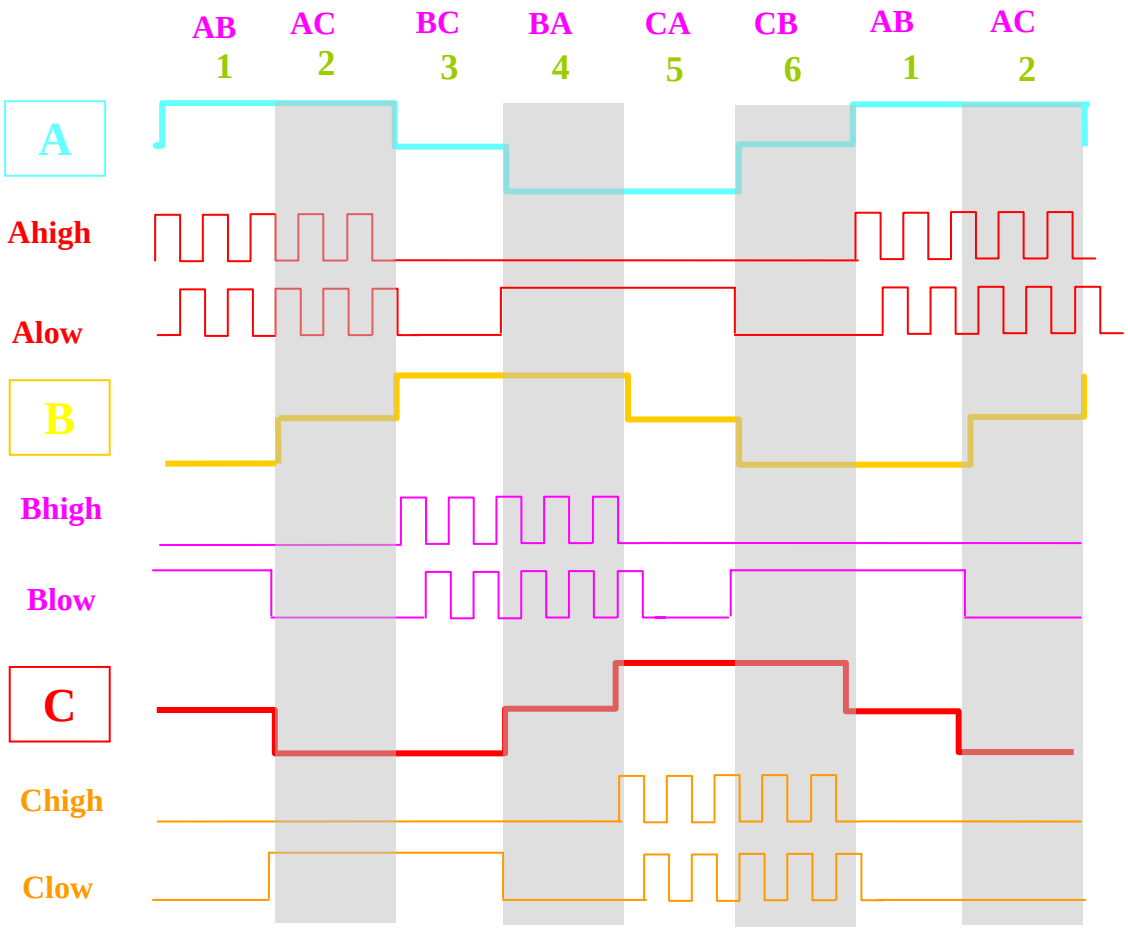


Figure 6.2.7.4 Complementary PWM

Phase	PhaseA_H	PhaseA_L	PhaseB_H	PhaseB_L	PhaseC_H	PhaseC_L
Phase1	PWM	PWM_L	0	1	0	0
Phase2	0	0	0	1	PWM	PWM_L
Phase3	0	1	0	0	PWM	PWM_L
Phase4	0	1	PWM	PWM_L	0	0
Phase5	0	0	PWM	PWM_L	0	1
Phase6	PWM	PWM_L	0	0	0	1

Table 6.2.7.4. Complimentary PWM phase sequence

6.2.8 BEMF Sensing Circuit

Most of the 3-phase motors only have 3 signals to the motor which are the winding connections. A Neutral point to the junction of these three windings is not available. A virtual Neutral point will have to be created in order to have a relative voltage level. The difference between the virtual neutral and the voltage of the floating terminal is used to detect BEMF. This is achieved using resistor network as shown in schematics. This virtual neutral point is connected to the negative input of the comparator module.

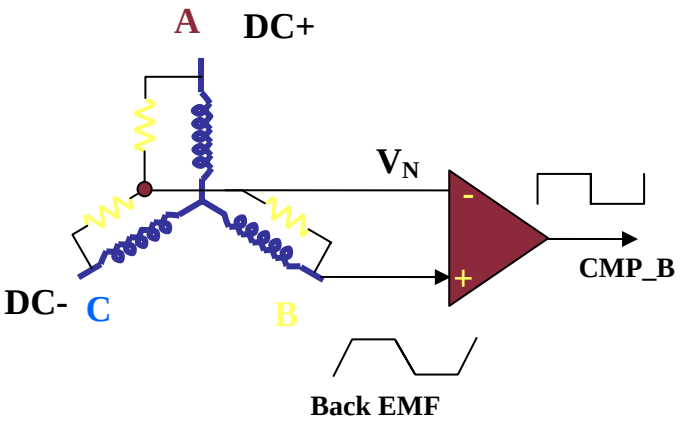


Figure 6.2.7.1 Floating winding BEMF compared to Virtual Neutral

To sense the BEMF properly a lot of attenuation and filtering is necessary. The motor winding voltages are scaled down to below 5V in the range of the comparator IC (LM339) input voltage ranges. The PWM frequency is filtered from the BEMF signal by additional High pass filters in the circuit as shown. The filtered signals are fed to the positive terminals of the comparator module. Figure 4.2.7.2 below shows the zero crossing detection circuit for the BEMF signal.

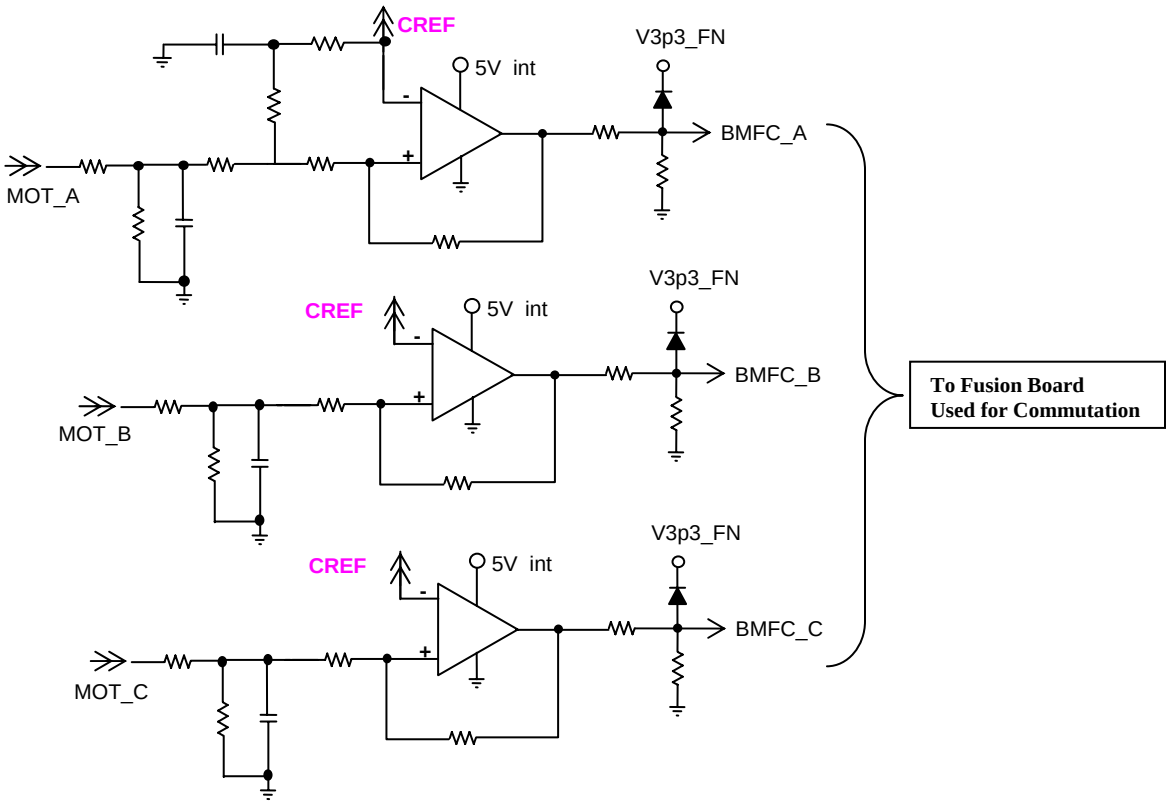


Figure 6.2.7.2 Floating winding BEMF compared to Virtual Neutral

The comparator outputs are then fed to the Fusion Board for auto commutate mode.

The raw motor windings contain too much spikes and noise which might exceed rated voltages of the Fusion Chip. Provision for giving this raw signal directly to Fusion is available on the board. Care has to be taken and ensured that the signals are within voltage and current limits in order to safe guard the Fusion I/O's. A provision for snubber circuit is made on board to suppress these spikes.

There is a mode where Fusion's ADC is being used to detect zero crossing based on BEMF measurements.

6.*2.9 BLDC Control State Machine*

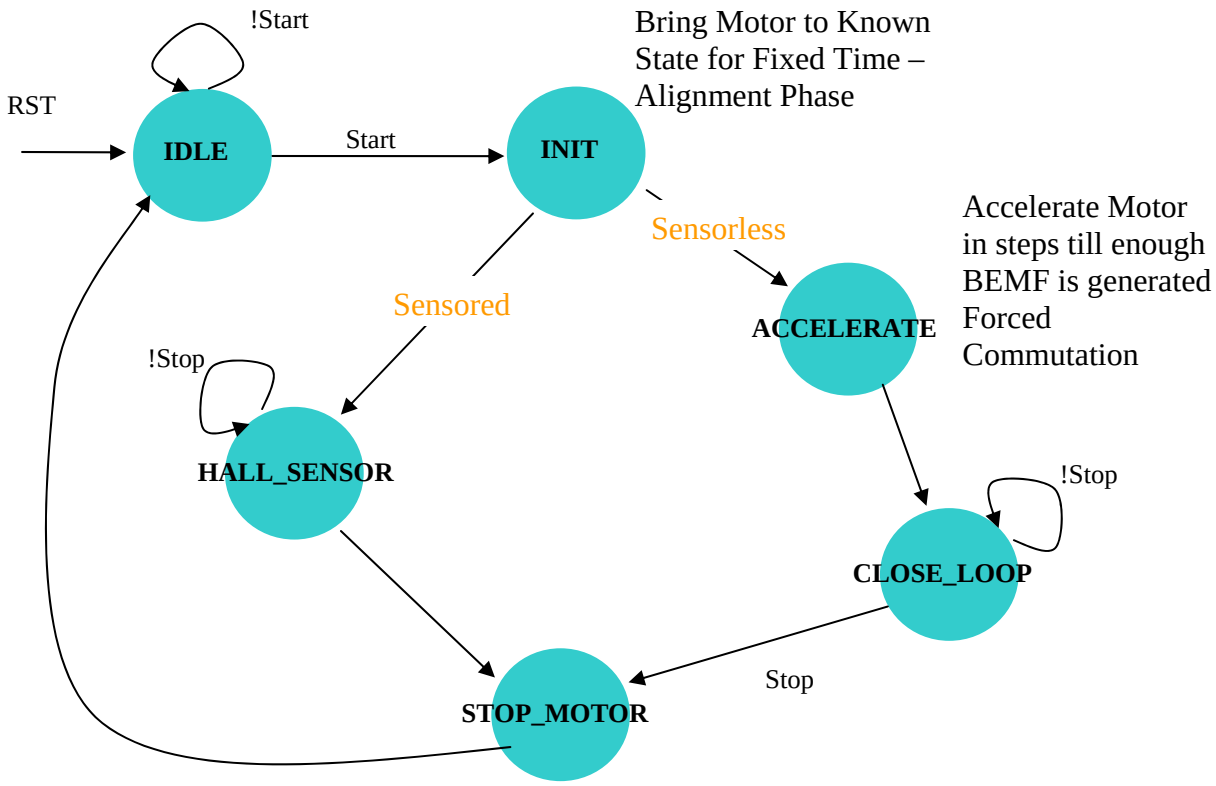


Figure 6.2.8 BLDC control state machine

6.2.10 BEMF Sensing using Fusion ADC

The motor voltages are scaled down by a factor of 10, to below 1.2V levels (If the motor supply is 12V), filtered and then applied to the Analog I/O's of Fusion.

The threshold flags are generated for every signal which toggles the output based on the value of the scaled motor voltages. These outputs are in the range of 0 to 3.3V. These threshold outputs are then applied to the daughter board to run the motor in Sensorless mode using Fusion ADC. In this mode also the motor has to go through the acceleration phase.

6.3. Brushed Drive

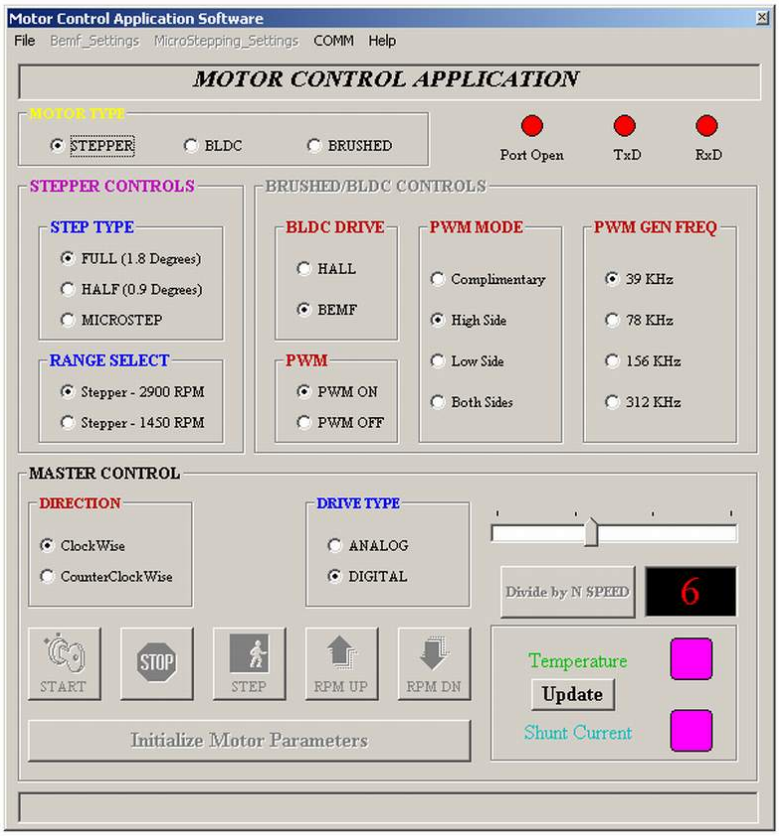
A DC Brushed Motor can be connected between the two Motor phases MOT_A and MOT_B on the back panel of the kit. Please ensure that the voltage rating of the motor is higher than the Motor Power Supply (12V, 5A) provided on the kit. Polarity of the motor is not important. The direction of the rotor movement can be altered using the DIR switch or the Clockwise/Counterclockwise button on the GUI.

At this time only one DC motor is supported.

7. Software Control

The application also contains PC master software, which supports communication between the Fusion Device and PC via an RS232 serial interface. This tool allows access to pre-assigned memory locations to control the motor parameters. The programmer can run the application using the GUI environment using a USB-to Serial Bridge available.

The picture below shows the opening screen of the MOTOR CONTROL APPLICATION Software Graphical User Interface.

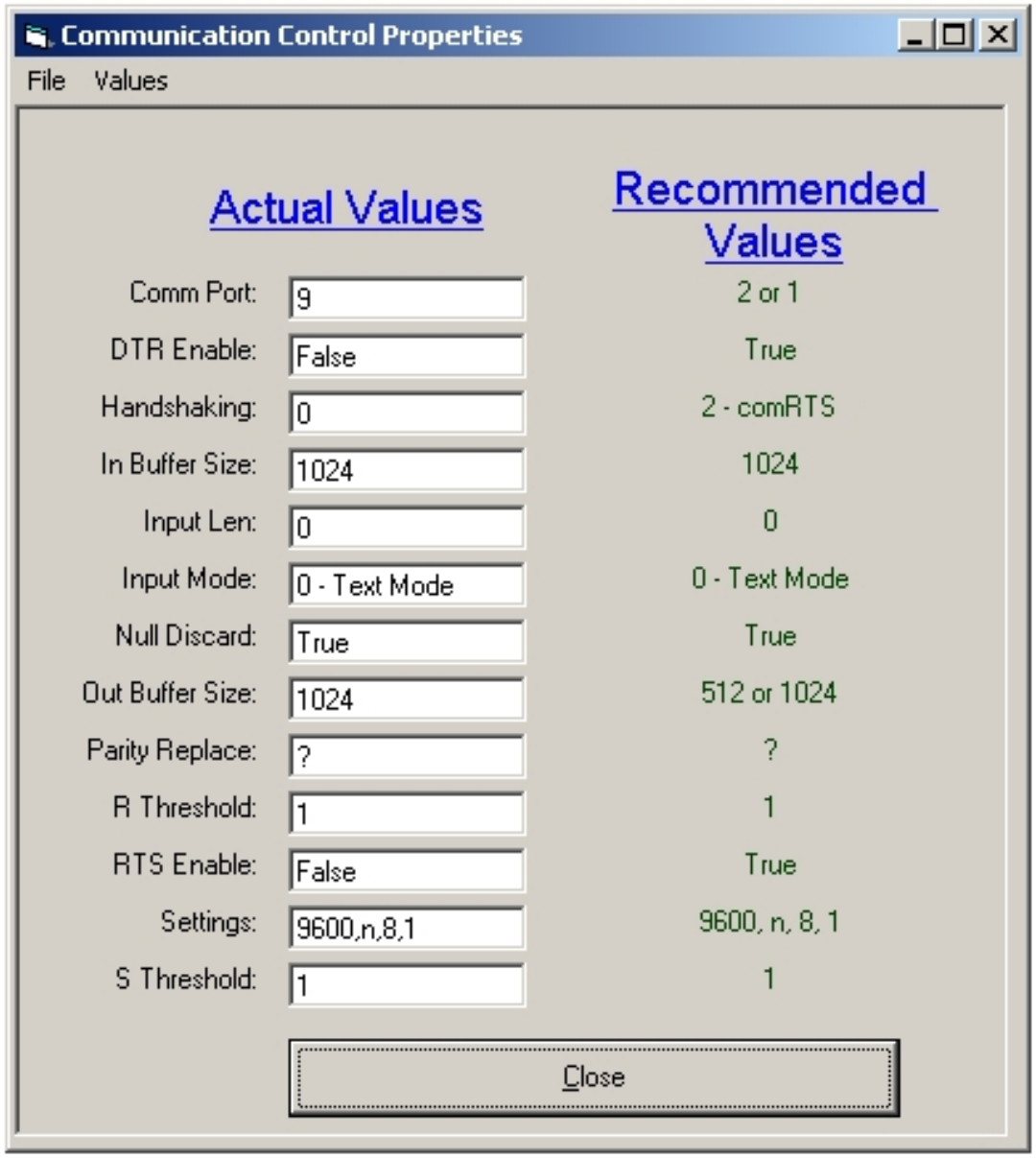


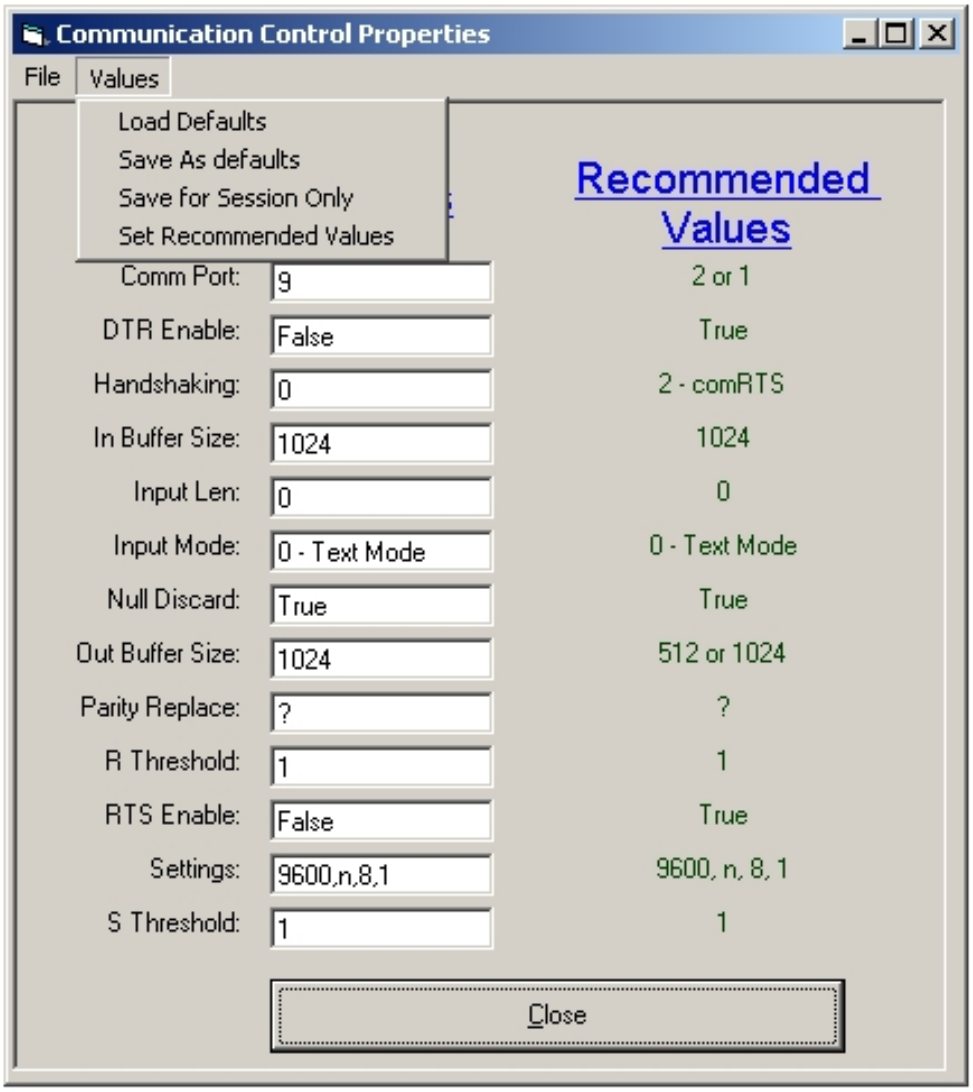
Communication Port:

The first step to start communication with daughter board is to set up the COM Port.

Com Port Settings:

Please verify the COM number assigned for the virtual com port generated by the OS when the RS232 to USB cable is plugged in. (Control Panel -> System -> Device Manager -> COM Port…) Also make sure all associated drivers for the USB to RS232 Interface cable is loaded prior to using this interface.


Communication Control Properties
File
Values
Actual Values
Recommended Values
Comm Port:
9
2 or 1
DTR Enable:
False
True
Handshaking:
0
2 - comRTS
In Buffer Size:
1024
1024
Input Len:
0
0
Input Mode:
0 - Text Mode
0 - Text Mode
Null Discard:
True
True
Out Buffer Size:
1024
512 or 1024
Parity Replace:
?
?
R Threshold:
1
1
RTS Enable:
False
True
Settings:
9600,n,8,1
9600, n, 8, 1
S Threshold:
1
1
Close


Communication Control Properties
File
Values
Load Defaults
Save As defaults
Save for Session Only
Set Recommended Values
Recommended Values
Comm Port: 9 2 or 1
DTR Enable: False True
Handshaking: 0 2 - comRTS
In Buffer Size: 1024 1024
Input Len: 0 0
Input Mode: 0 - Text Mode 0 - Text Mode
Null Discard: True True
Out Buffer Size: 1024 512 or 1024
Parity Replace: ? ?
R Threshold: 1 1
RTS Enable: False True
Settings: 9600,n,8,1 9600, n, 8, 1
S Threshold: 1 1
Close

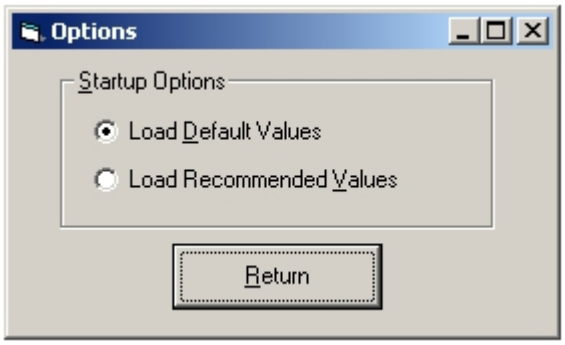
Load Defaults: Load Default values into the Actual Values column

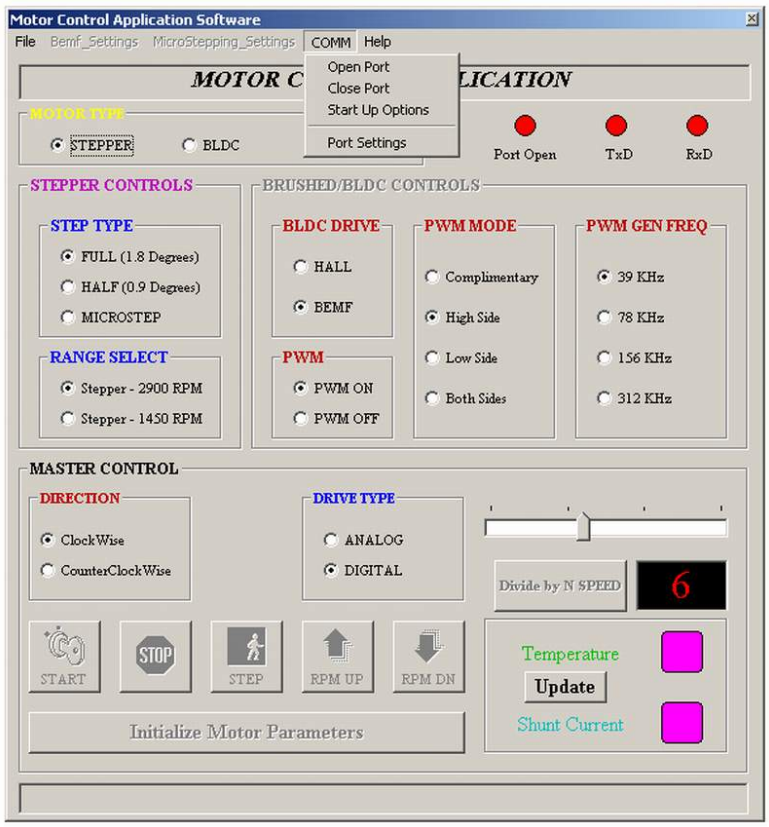
Save As Defaults: Save the Actual Values to Registry so next time these settings would be restored.

Save for Session Only: The changes in the Values will not be updated to the registry, so this mode will temporarily change the settings, the default values in the registry would not be changed.

Set Recommended Values: Load recommended values into actual values column.

Startup Options:
Using 'Startup Options' option in 'COMM' menu you can load default settings or recommended settings. The default options are the one that have been stored in the registry.





Click on 'Open Port' option from 'COMM" Menu bar. 'Port Open' indicator on the screen turns green from red this indicates that the communication port is successfully opened and ready for communication.

Click on 'Close Port' to close any open ports. It is recommended that you close the port before exiting the program.

MOTOR TYPE:
Choose the 'MOTOR TYPE' out of the three options 'STEPPER', 'BLDC' or BRUSHED. The options available for the respective motor would be activated for modifications.

COMMON CONTROLS

The controls in this window except 'STEP' are common for both bldc and stepper. Before we start motor we have to 'initialize motor parameters'. This step is very important . All settings you choose on the screen to run motor get refreshed when you click on 'Initialize Motor Parameters' otherwise motor will run on your previous settings. When you click on 'option' in 'COMM menu you can change the settings such as the baud rate, handshaking enable etc. All these setting are stored in registry in HKEY_CURRENT_USER -> software -> VB and VBA program settings -> motor control application -> properties.

DIRECTION controls the direction of rotation of motor. Motor speed control can be ANALOG i.e. through potentiometer connected to pin AV0 (M6) or DIGITAL (RPM UP/ RPM DN).

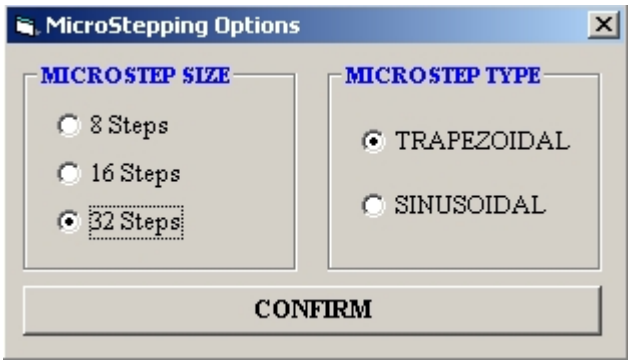
START and STOP controls to start and stop the motor respectively.
RPM UP /RPM DN for increasing or decreasing speed respectively when in digital control mode.

STEPPER CONTROLS

- STEP TYPE
  Stepper motor can be run in FULL STEP, HALF STEP or MICRO STEP mode.
  Full Step Mode: In this case the stepper motor rotates by 1.8 degrees per STEP Click. (i.e. 200 Full Steps for one complete revolution of the motor shaft)

  Half Step: In this mode the stepper motor rotates by 0.9 degrees per STEP Click (i.e. 400 Half Steps for one complete revolution of the motor shaft)

  Microstep Mode: Microstepping can be done using Trapezoidal method or sine method
  with 8, 16 and 32 microsteps



  Stepper Motors can give very high precision in angle of rotation, and commonly used in Automation and Motion Control Applications.

- RANGE SELECT
  For different motors maximum RPM rating is different so two ranges are provided. In one case we get a maximum of 1440RPM and in another case we get maximum 720RPM.
  In microstep mode Range select does not affect the speed range.

- STEP
  When you click on 'STEP' you can single step the stepper motor in full or half step mode. Single step does not work in Microstepping mode.

BLDC CONTROLS

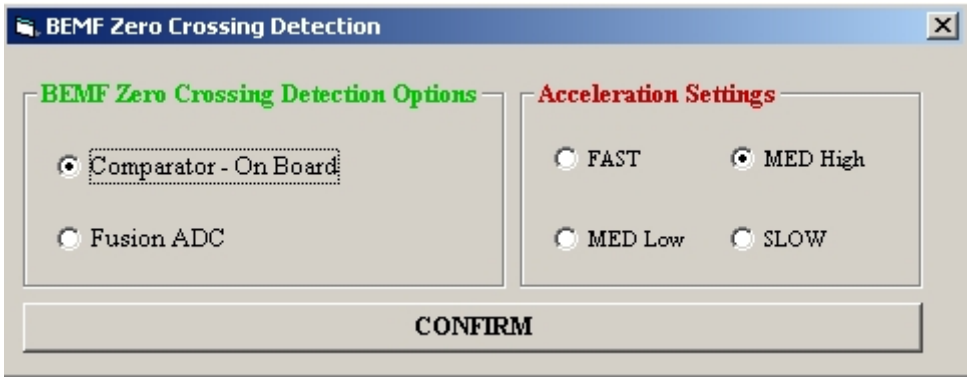
- BLDC DRIVE
  For Sensored Commutation Use HALL Mode
  For SensorLess Commutation use the BEMF Option.

- PWM
  When PWM ON is selected we can have speed control using RPM UP and RPM DN . The Duty Cycle and consequently the average voltage to the Motor winding are altered to increase or decrease the speed of the motor.

  When PWM OFF is selected the RPM is at its maximum per applied voltage. In that the case the RPM can be varied only with External Motor Supply voltage (Make sure the motor voltage does not exceed the specifications)

- PWM MODE SELECT
  A BLDC Motor can run in four modes
  1. Complimentary : in this mode free wheeling current flows through MOSFETS and PWM is applied to high side MOSFET drivers.
     (The complimentary mode consumes a lot of current at low speeds, this mode is not recommended for use and only a BETA feature)
  2. High Side: PWM is applied to only high side MOSFET drivers.
  3. Low Side: PWM is applied to only low side MOSFET drivers.
  4. Both Sides: PWM is applied to high side as well as low side MOSFET drivers.

- MOTOR DRIVE
  HALL: This option is for motors having Hall sensors for auto-commutation.
  BEMF: This option is for motors that do not have sensors and need to be driven using BEMF Method.



Note: In case of BEMF feedback motor needs to be forcibly driven in openloop (acceleration phase) initially so that back emf of considerable magnitude is generated. Once enough BEMF is generated the motor is shifted to closeloop i.e. motor is driven as per BEMF feedback. In case of Sensored operation, there is no need to run the motor in open loop.

BEMF Zero Crossing Detection Options:

- Comparator – On Board – Use the comparators LM339 provided on board to do the zero crossing detection to drive the BLDC in sensorless mode.

- Fusion ADC – Use the scaled version of the winding voltages to generate threshold flags from Fusion ADC

Also the BEMF is a function of RPM. The motor needs to be run open-loop until a good enough BEMF is generated for automated commutation.

Acceleration Settings:

- FAST is for very high speed motor (30000 to 40000rpm): In this case the motor accelerates to higher rpm quickly so power consumption is minimal
- MEDIUM HIGH and MEDIUM LOW is for Mid Range Motors (@ 11000 - 30000rpm).
- LOW setting is for low speed motors (2300rpm).

The acceleration time is long in LOW setting hence the consumption of current is also very high during the acceleration period.

Choose the appropriate acceleration time for the motor you plan to drive. In the current setup, for Maxon EC45 Flat, use MEDIUM HIGH or MEDIUM LOW setting.

PWM FREQUENCY

Four different PWM frequencies are provided which are used to generate PWM signal. You can run motor on different PWM frequencies.

8. Fusion Software Control Register Map

Communication Data Format:

Bits	Description
ADDRESS[2:0]	3 Bit Address to address 8 register locations of 4 bit data bank
DATA[3:0]	4-bit Data to be written to or Read from the addressed location
W_R	1 = Write to Specified Register 0 = Read from Specified Register

CTR_REG_0 (ADDRESS[2:0] = 000) - Read-Write

Bits	Name	Description
3	RUN	Start the Motor
2	STOP	Stop the Motor
1	PLUS	Increase the Speed/RPM of Motor (Digital Control)
0	MINUS	Decrease the Speed/RPM of Motor (Digital Control)

CTR_REG_1 (ADDRESS[2:0] = 001) - Read-Write

Bits	Name	Description
3	STEP	Single Step the Stepper Motor CTR_REG_2[2] will decide Full Step or Half Step Full Step = 1.8 Degree/Step = 200 Steps per Rev Half Step = 0.9 Degree/Step = 400 Steps per Rev
[2:1]	Reserved	Reserved for Future Use
0	SYS_RST	Software System Reset

CTR_REG_2 (ADDRESS[2:0] = 010) - Read-Write

Bits	Name	Description	
3	CW_OR_CCW	Stepper, BLDC or Brushed Motor 1 Rotation Direction 1 = Motor will rotate in Clockwise Direction 0 = Motor will rotate in Counterclockwise Direction	
2	FULL_OR_HALF	CTR_REG_5[0] = 1 Stepper Motor	This control bit is used to select the Full step or Half step mode when Microstepping is off. (CTR_REG_4[1] = 0) 1 = Full Step Mode (200 Steps/Rev) 0 = Half Step Mode (400 Steps/Rev)

1	STEPPER_RNG	CTR_REG_5[0] = 1 Stepper Motor	Stepper Motor Range Select 1 = Maximum speed 1440 RPM 0 = Maximum speed 720 RPM *Note: For rpm calculation refer to sec. in user guide*
0	MST_SC_OR_PWM	CTR_REG_5[0] = 1 Stepper Motor	Microstepping is TZ/SINE Form 1= Microstepping in Trapezoidal form. 0= Microstepping in sine form.
		CTR_REG_5[0] = 0 Brushed or Brushless Motor	For Brushed or Brushless Motor this control is used to Turn PWM ON or OFF 1= PWM ON. 0= PWM OFF.

CTR_REG_3 (ADDRESS[2:0] = 011) - Read-Write

Bits	Name	Description	
[3:2]	NO_MSTP_OR_BL_MD[1:0]	CTR_REG_5[0] = 1 Stepper Motor	Number of Steps in Microstepping Mode 00 = 8 Steps 01 = 16 Steps 10 = 32 Steps 11 = Reserved
		CTR_REG_5[0] = 0 Brushed or Brushless & CTR_REG_4[1] = 0 Brushless	Mode of Operation of BLDC Motor 00 = Complementary drive. 01 = PWM control to high side BLDC drivers. 10 = PWM control to low side BLDC drivers. 11 = PWM control to high side as well as low side BLDC drivers.
[1:0]	PWM_FREQ_SEL[1:0]	For brushed and brushless motor these two bits are used to select the PWM Frequency 00 = 39 kHz 01 = 78 kHz 10 = 156 kHz 11 = 312 kHz	

CTR_REG_4 (ADDRESS[2:0] = 100) - Read-Write

Bits	Description	Description	
[3:2]	BL_TAC[1:0]	CTR_REG_5[0] = 0 Brushed or Brushless & CTR_REG_4[1] = 0 Brushless	Brushless Motor Acceleration Time in BEMF Mode 00 = 208ms 01 = 312ms 10 = 520ms 11 = 3.74sec Note: For Acceleration time calculations refer to Section … in User Guide
[1]	MST_OR_BD_BL	CTR_REG_5[0] = 1 Stepper motor	1 = MicroStepping on. 0 = MicroStepping off.
		CTR_REG_5[0] = 0 Brushed or Brushless	1 = Brushed Motor. 0 = Brushless Motor.
[0]	Reserved	Reserved	

CTR_REG_5 (ADDRESS[2:0] = 101) - Read-Write

Bits	Name	Description
[3]	HALL_OR_BEMF	This control is used for brushless motor (CTR_REG_5[0]=0 & CTR_REG_4[1]=0) only. 1 = Feedback using hall sensor. 0 = Feedback using back EMF.
[2]	COMP_OR_ADC	This control is used for brushless motor (CTR_REG_5[0]=0 & CTR_REG_4[1]=0) only. 1 = It will use comparator to sense the back BEMF (zero crossing). 0 = It will use ADC to sense the back BEMF (Zero crossing). Because of pin limitation this (COMP_ADC) feature is not implemented.
[1]	A_OR_D	This control is used to select analog speed control or digital speed control for all the motors. 1 = Analog control through potentiometer 0 = Digital control
[0]	STEPPER_OR_BDBL	This control is used to select drive for stepper motor or drive for dc motor (Brushed or Brushless Motor) 1 = Stepper Motor 0 = Brushed or Brushless Motor

CTR_REG_6 (ADDRESS[2:0] = 110) - Read-Write

Bits	Name	Description
[3:0]	Reserved	Reserved

CTR_REG_7 (ADDRESS[2:0] = 111) - Read-Only

Bits	Name	Description
[3:2]	OC[1:0]	These two bits indicate the current in motor windings. (Ampere) 00 = Current < 0.5A 01 = 0.5A < Current < 1A 10 = 1A < Current < 2A 11 = Current > 2A
[1:0]	OT[1:0]	These two bits indicate the temperature of motor. (Degree C) 00 = Temperature < 30 01 = 30 < Temperature 40 10 = 40 < Temperature 50 11 = Temperature > 50

9 APPENDIX

9.1 Appendix A- AFS600 FG256 Pin List

Signal Name	Input/ Output	Description	Fusion Pin
RxD	Input	RS232 Receive	F3
TxD	Output	RS232 Transmit	F1
CW_OR_CCW_H	Output	Motor Direction Control 1 – Clockwise 0 – Counterclockwise	J6
ATRETURN89	Input	Temperature Sensor – Return	T12
AT	Input	Temperature Sensor	R12
AV1	Input	Over Current Sense Voltage Input	P6
AC1	Input	Over Current Sense Current Input	M7
AV0	Input	RPM Control – Analog	M6
AV2	Input	Scaled down BEMF voltage for phase A	M9
AV3	Input	Scaled down BEMF voltage for phase B	N7
AV4	Input	Scaled down BEMF voltage for phase C	N9
NO_MSTP_OR_BL_MD_H [1:0]	Output	For Stepper Motor, in micro step mode No. of Micro step 00- 8steps 01- 16steps 10- 32steps 11- Reserved For BLDC motor, PWM Mode 00 – Complementary PWM 01 – Low Side PWM 10 – High Side PWM 11 – Both Sides PWM	H12, H14
STOP_H	Output	Motor Stop	F4
MST_SC_OR_PWM_H	Output	For stepper motor, Microstepping ON 1- Trapezoidal Form, 0- Sinusoidal Form For brushed or brushless motor PWM ON 1 – ON, 0 – OFF	K16
MST_OR_BD_BL_H	Output	For stepper motor Microstepping ON/OFF 1- ON, 0- OFF For Brushed/Brushless motor 1- Brushed motor, 0- Brushless motor	K4
STEPPER_OR_BDBL_H	Output	Motor Select 1 – Stepper Motor 0 – BLDC Motor	K3

RUN_H	Output	Motor Start/Run	F2
BEMF_COMP_A	Input	BEMFA – DB Comparator output	L1
BEMF_COMP_B	Input	BEMFB – DB Comparator output	L3
BEMF_COMP_C	Input	BEMFB – DB Comparator output	M2
RANGE_SELECT_H	Output	Stepper Motor Range Select ON – 1440 RPM, OFF – 720 RPM	G14
SYS_RESET	Input	System Reset (Pulse through Switch SW6)	L15
FAULT_OT	Output	Over Temperature Fault Detection	N2
PHASEA_H	Output	PhaseA – High Side Signal	J5
PHASEA_L	Output	Phase A – Low Side Signal	J3
PHASEB_H	Output	PhaseB – High Side Signal	J1
PHASEB_L	Output	PhaseB – Low Side Signal	K1
PHASEC_H	Output	PhaseC – High Side Signal	K6
PHASEC_L	Output	PhaseB – Low Side Signal	L2
PHASED_H	Output	PhaseD – High Side Signal	L4
PHASED_L	Output	PhaseB – Low Side Signal	M3
FULL_HALF_OR_CAD_H	Output	For stepper motor Step Size when microstepping off 1 – Full Step (200 steps per revolution) – 1.8 degrees per step 0 – Half Step (400 steps per revolution) – 0.9 degrees per step For BLDC motor 1- BEMF drive using on board comparator 0- BEMF drive using ADC	J4
HALL_A	Input	Hall Sensor A from Motor	G6
HALL_B	Input	Hall Sensor B from Motor	G1
HALL_C	Input	Hall Sensor C from Motor	H2
BL_TAC_H[1:0]	Output	Acceleration Control 00– 206 milliseconds 01– 312 milliseconds 10– 520 milliseconds 11– 3.74 Seconds	H16, G11
FAULT_OC	Output	Over Current Fault Detection	M5
SD	Output	Shutdown - Can be caused by FAULT_OC or FAULT_OT	L5
HALL_OR_BEMF_H	Output	Sensor Mode ON – Hall Sensor Operation OFF – BEMF Operation	N1
STEP_H	Output	Step Motor in Half or Full Step depending on FULL_HALF_STEP_H	G4
HW_SW	Output	Hardware or Software Control ON – Hardware, OFF – Software	N3
PLUS_H	Output	Increment Speed	G3

MINUS_H	Output	Decrement Speed	H1
PWM_FREQ_SEL_H[1:0]	Output	PWM Frequency Select 00 – 39 KHz, 01 – 48 KHz 10 – 105 KHz, 11 - 312 KHz	J14,J15
A_OR_D_H	Output	Analog or Digital Control of RPM 1- Analog through Potentiometer on AV0 0 – Digital through PLUS_H and MINUS_H keys (if hardware)	J2
R_nW_LCD	Output	Read Write signal for LCD Panel	E5
RS_LCD	Output	LCD control signal	D1
EN_LCD	Output	Enable LCD Signal	D3
DATA_LCD[3:0]	Output	4 Bit LCD data bus	E2, E3, F5, F6
CHK_TEMP	Output	Test signal	A11
BAUD_RATE_SEL[2:0]	Input	Baud Clock setting for serial communication	H11, H13, H15
CHK_CURRENT	Output	Test signal	B11
rpm_value[7:0]	Output	8 bit PWM setting displayed on Fusion MB LED's	A14, B14, A13, B13, D11, E11, C13, B12

9.2 APPENDIX B- Motor connections

Legend for back panel connections (The four motor connections on the daughter board are brought out to the back panel as MOT_A, MOT_B, MOT_C and MOD_D respectively)

The color coding for these 4 connections are as follows:

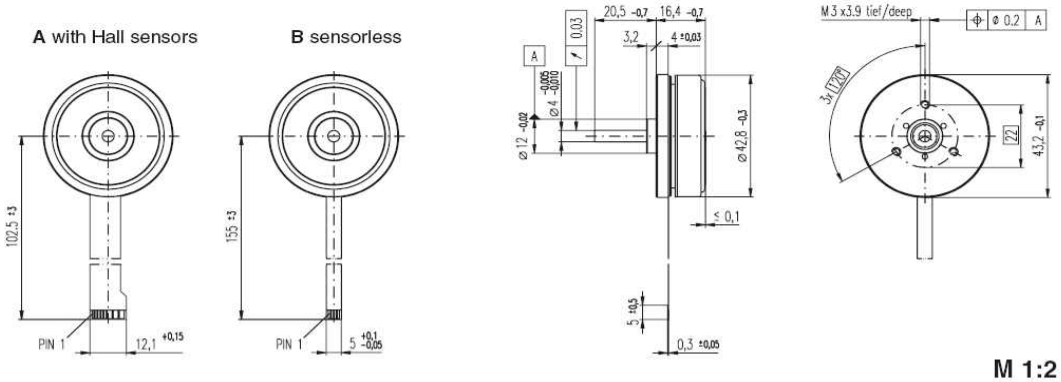
From Daughter Board	Color Code	Back Panel of the Kit
Phase 'A'	**Orange**	MOT_A (To Back Panel)
Phase 'B'	**Yellow**	MOT_B (To Back Panel)
Phase 'C'	**Green**	MOT_C (To Back Panel)
Phase 'D'	**Gray**	MOT_D(To Back Panel)

NOTE: Only One Motor can be connected to the daughter board via this back panel.

Refer to the motor connection legend that follows the motor specifications.

BLDC Motor:

EC 45 Flat motor ∅45 mm, brushless, 30 Watt



M 1:2

Stock program
Standard program
Special program (on request!)

		Order Number	
	with Hall sensors	200142	
	sensorless		200189
Motor Data			
1	Assigned power rating	W	30	30
2	Nominal voltage	Volt	12.0	12.0
3	No load speed	rpm	4400	4400
4	Stall torque	mNm	260	220
5	Speed / torque gradient	rpm / mNm	17.5	20.5
6	No load current	mA	150	150
7	Terminal resistance phase to phase	Ohm	1.20	1.40
8	Max. permissible speed	rpm	10000	10000
9	Max. continuous current at 5000 rpm	A	2.30	2.30
10	Max. continuous torque at 5000 rpm	mNm	53.8	53.8
11	Max. efficiency	%	77.6	76.0
12	Torque constant	mNm / A	25.5	25.5
13	Speed constant	rpm / V	374	374
14	Mechanical time constant	ms	17.0	20.0
15	Rotor inertia	gcm²	92.5	92.5
16	Terminal inductance phase to phase	mH	0.410	0.410
17	Thermal resistance housing-ambient	K / W	4.0	4.0
18	Thermal resistance winding-housing	K / W	6.0	6.0
19	Thermal time constant windings	s	11.6	11.6
20	Thermal time constant stator	s	42.2	42.2

Specifications

- Axial preload > 5 N
- Max. **ball bearing** loads
  axial (dynamic) 2.8 N
  radial (7.5 mm from flange) 5.5 N
  Force for press fits (static) 50 N
  (static, shaft supported) 1000 N
- Ambient temperature range -40 ... +100°C
- Max. permissible winding temperature +125°C
- Weight of motor 88 g
- Version with and without Hall sensors
- 16 pole permanent magnet
- 3 phased coil stator with 4 pole shoes each
- Values listed in the table are nominal.
- **Connection** | **with Hall sensors** | **sensorless**

Pin 1	4.5 ... 18 VDC	Motor winding 1
Pin 2	Hall sensor 3*	Motor winding 2
Pin 3	Hall sensor 1*	Motor winding 3
Pin 4	Hall sensor 2*	⊥ neutral point
Pin 5	GND	
Pin 6	Motor winding 3	
Pin 7	Motor winding 2	
Pin 8	Motor winding 1	

- **Adapter** | **Order number** | **Order number**

see p. 275	220300	220310

- **Connector** | **Article number** | **Article number**

AMP	1-487951-1	487951-4
MOLEX	52207-1190	52207-0490
MOLEX	52089-1110	52089-0410

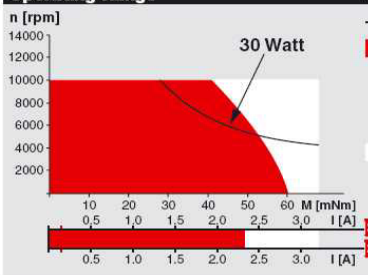
Pin for design with Hall sensors:
FPC, 11 pole, pitch 1.0 mm, top contact style

*Internal pull-up (7 ... 13 kΩ) on pin 1

- For wiring diagram for Hall sensors, see p. 26

Operating Range

Comments Details on page 149



Curve of constant assigned power rating

Continuous operation
In observation of above listed thermal resistances (lines 17 and 18) the maximum permissible winding temperature will be reached during continuous operation at 25°C ambient.
= Thermal limit.

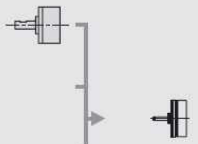
Short term operation
The motor may be briefly overloaded (recurring).

200189 Motor with high resistance winding
200142 Motor with low resistance winding

maxon Modular System

Overview on page 17 - 21

Spur Gearhead
∅45 mm
0.5 - 2.0 Nm
Details page 226



Recommended Electronics:

AECS 35/3	page 262
DEC 50/5	264
DECV 50/5	265
EPOS 24/1	271
EPOS 24/5	271
Notes	17

April 2005 edition / subject to change

maxon EC motor 187

BLDC Motor Wiring Diagram:

	Color Code	Motor Connections
Phase 'A'	**Red**	MOT_A (To Back Panel)
Phase 'B'	**Blue**	MOT_B (To Back Panel)
Phase 'C'	**Green**	MOT_C (To Back Panel)
Hall 'A'	**Brown**	Connect to 5 Pin Right Angle connector as per the Board Legend (J2- HALL) (This connector is pre-connected)
Hall 'B'	**Orange**	
Hall 'C'	**Yellow**	
Ground	**Black**	
Vcc	**Red**	

Note: Only one motor can be connected to the back panel.

For sensorless operation it is not necessary to remove the Hall connections.

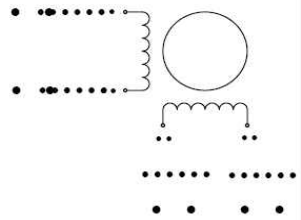
Stepper Motor: (Hybrid Stepping Motor Type 14HY5401) (www)

REV. F

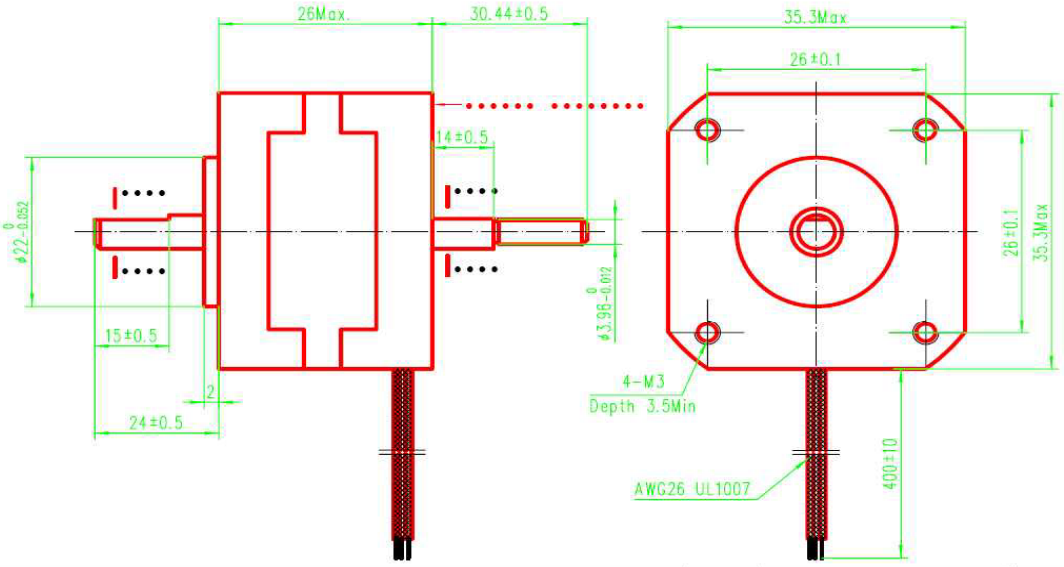
HYBRID STEPPING MOTOR

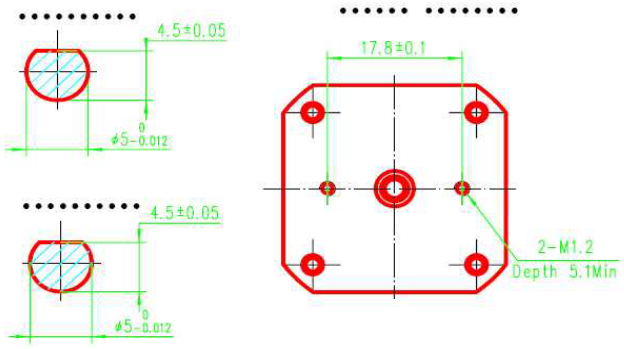
General specifications		Electrical specifications	
Step angle	1.8° ±5%	Rated voltage	3.225 V
Number of phase	2	Rated current	0.75 A
Insulation resistance	100Mohm Min.(500V DC)	Resistance per phase	4.3Ω ±10% ohm
Insulation class	Class B	Inductance per phase	4Ω ±20% mH
Rotor inertia	12 g·cm²	Holding torque	70 mNm
Mass	0.12 kg	Detent torque	10 mNm

Wiring Diagram



Dimensions unit=mm





REV.	REVISIONS	DATE
C	ADD COMMENT (BLACK COVER)	2003.12.22
D	CHANGE K1-K1	2003.12.25
E	CHANGE MASS	2005.8.24
F	CHANGE BEARING from 619/5-2Z to 625-2Z Change Back Endcaps from 15.75±0.13 to 17.8±0.1	2006.8.29

comment:

1. BLACK ENDCAPS
2. Use 625ZZ bearing

MS9.005.180

AS-14HY-ODL-0010

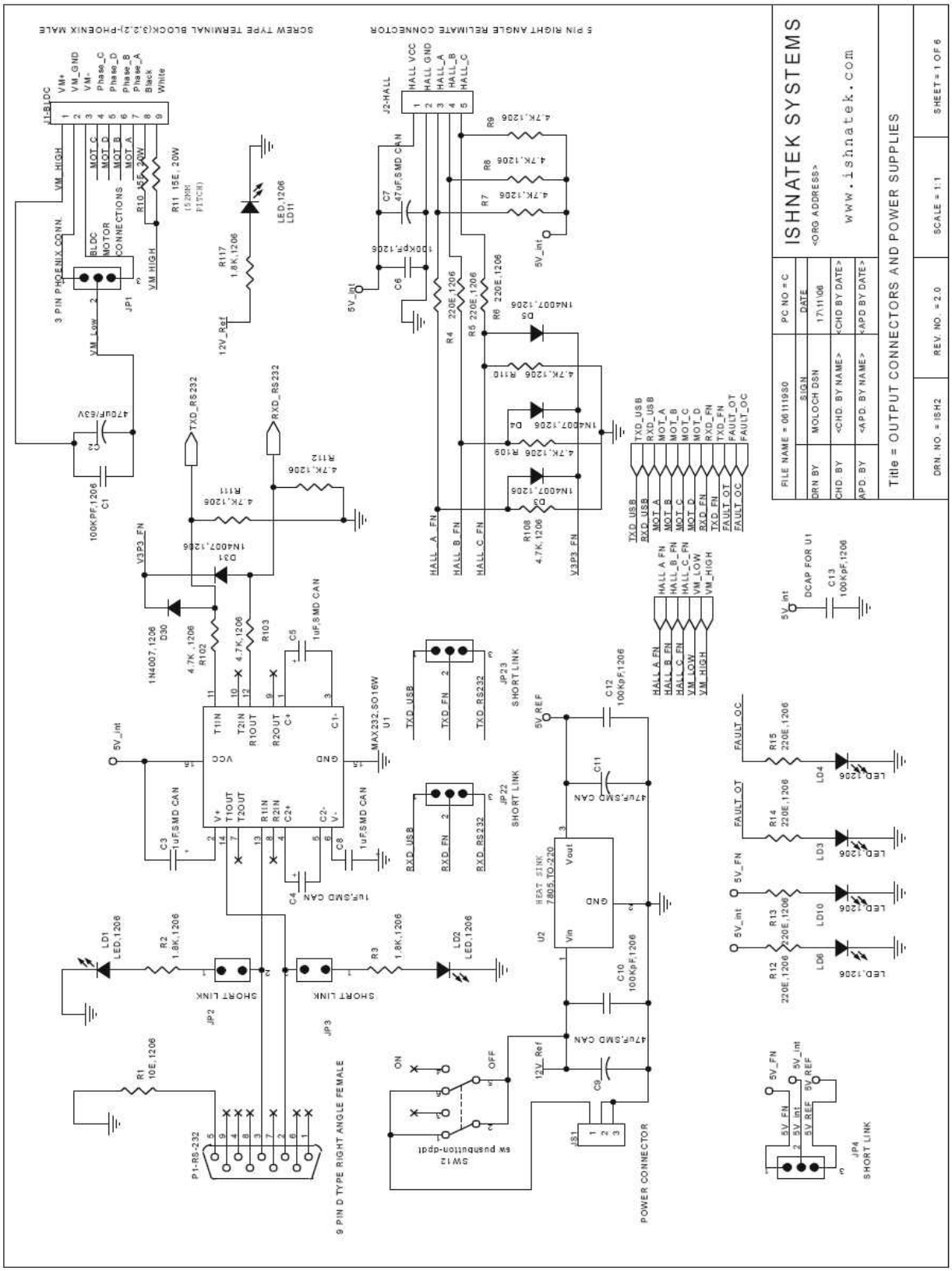
STD.		APPR.		DWG.	罗智敏/06.8.29	TECH.	

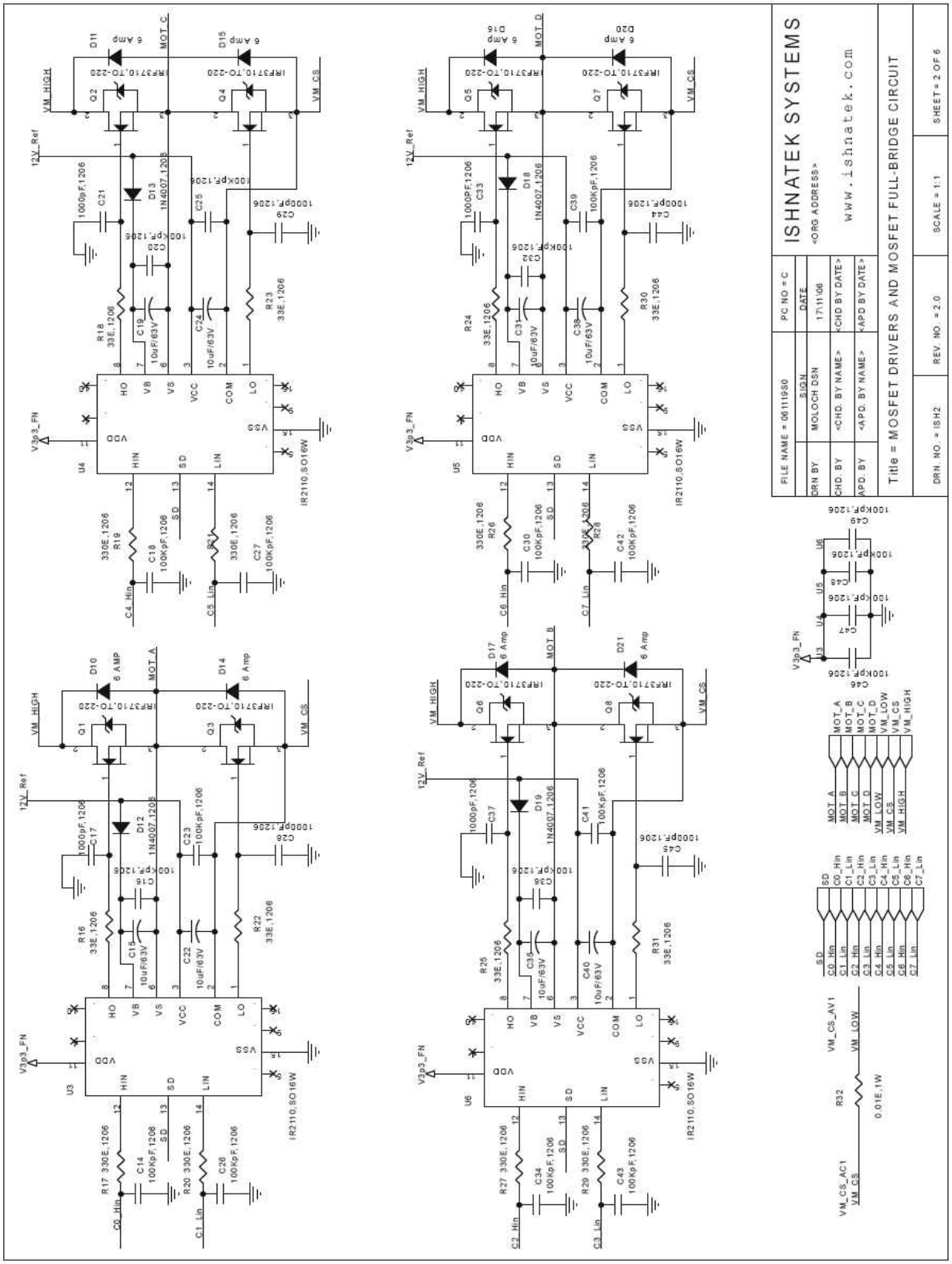
Stepper Motor Wiring Diagram:

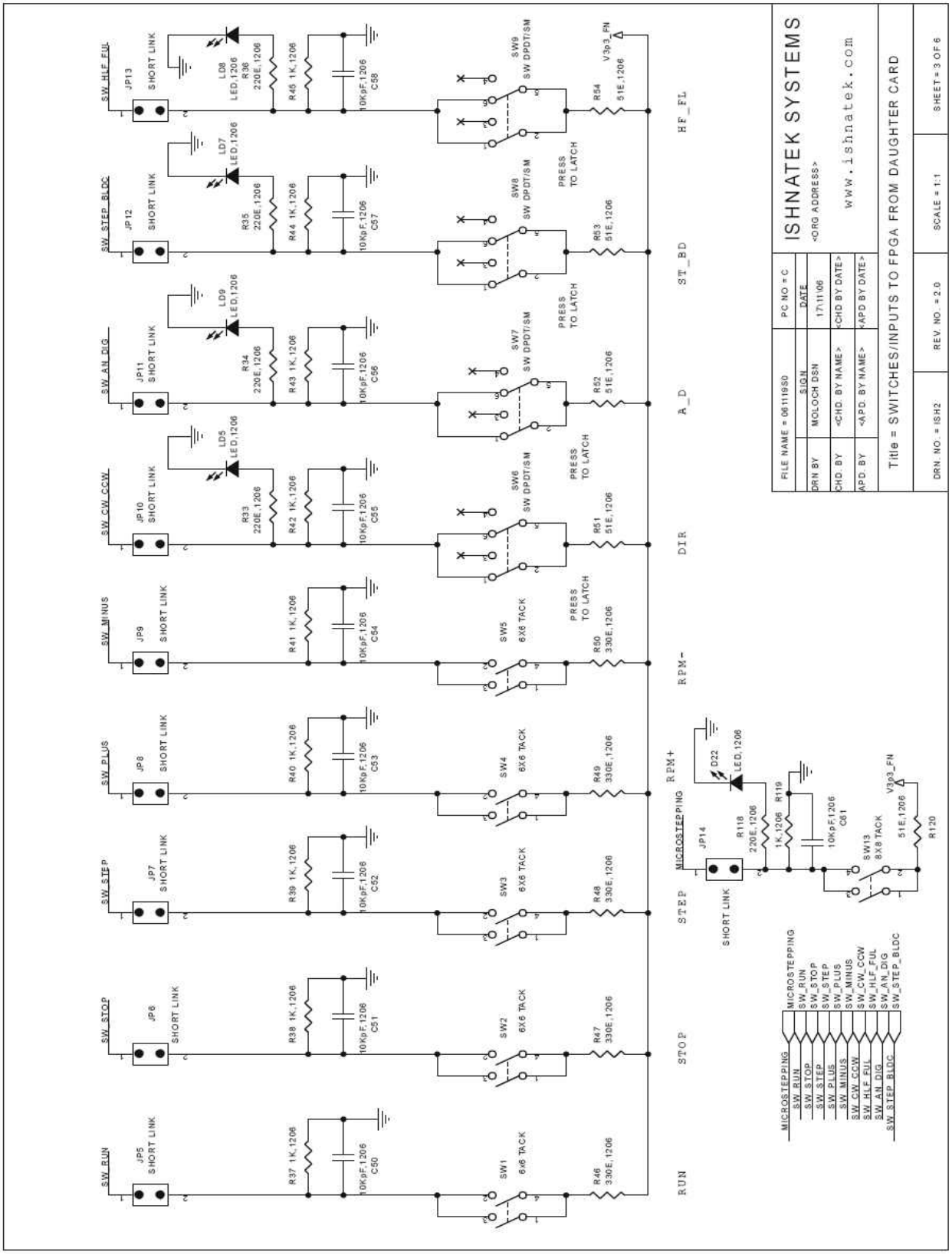
	Original wire/leads on the motor	Motor Connections
Phase 'A'	**Red**	MOT_A (To Back Panel)
Phase 'B'	**Blue**	MOT_B (To Back Panel)
Phase 'C'	**Green**	MOT_C (To Back Panel)
Phase 'D'	**Black**	MOT_D (To Back Panel)

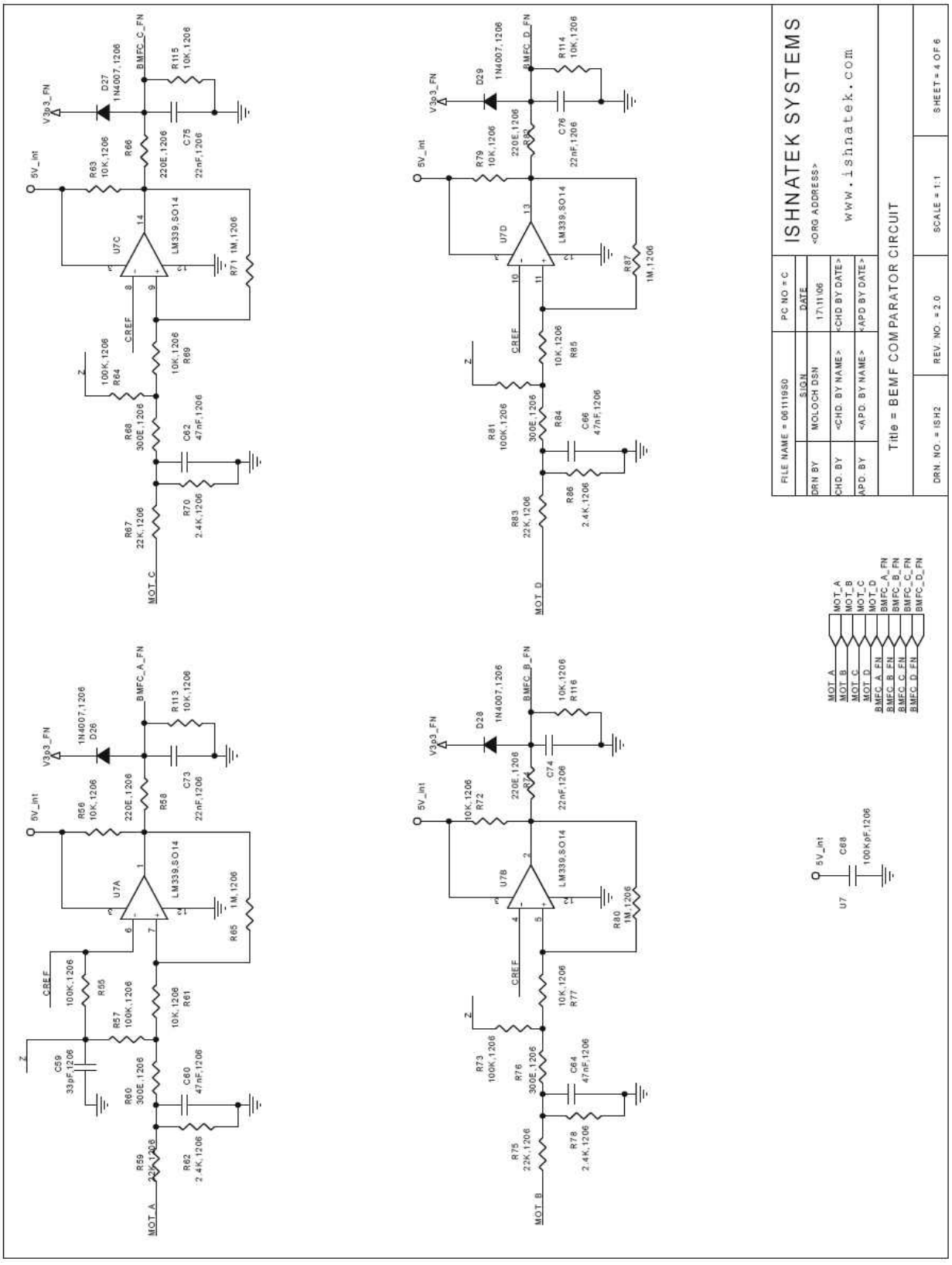
Note: Only one motor can be connected to the back panel.

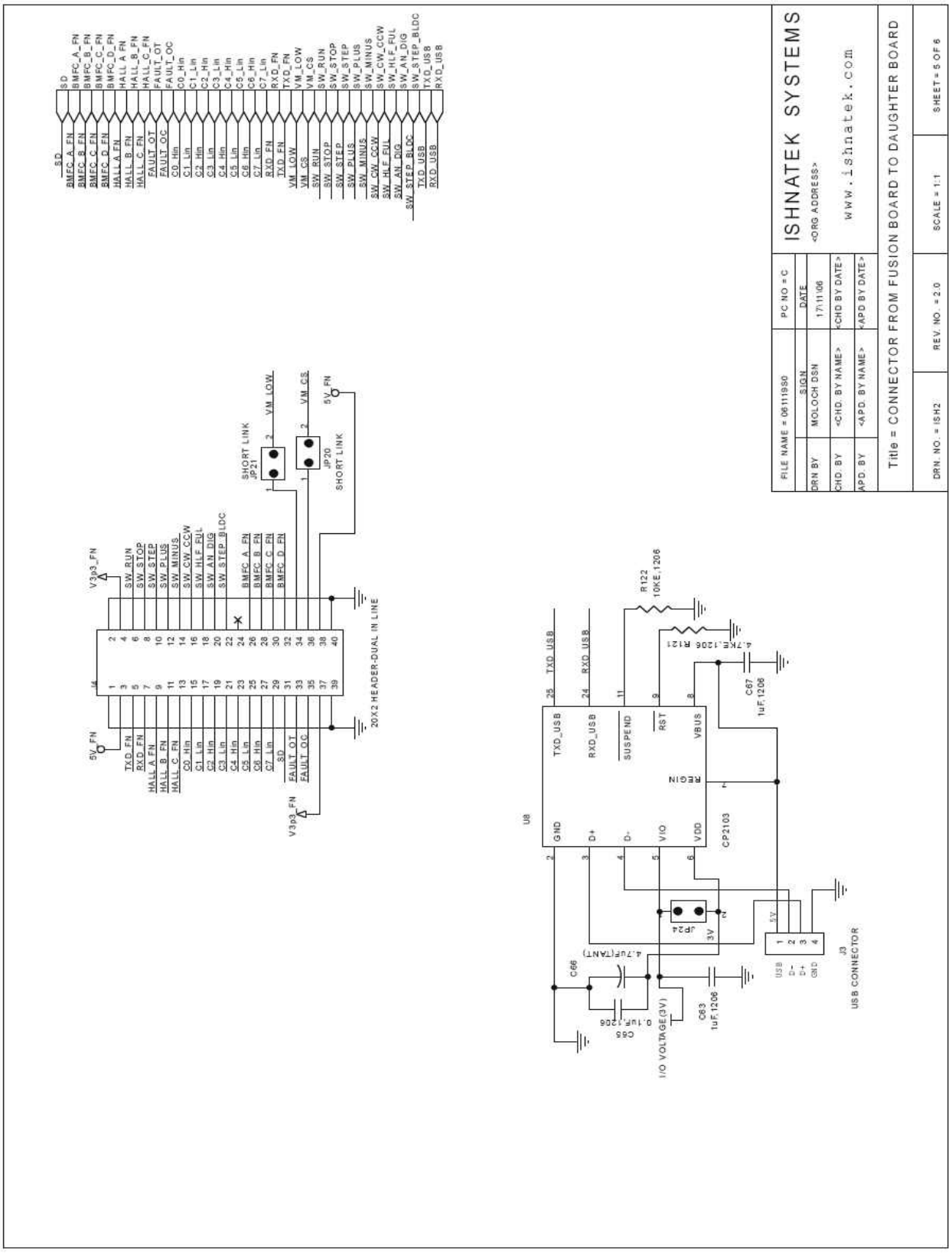
9.3 APPENDIX C- Board Schematics

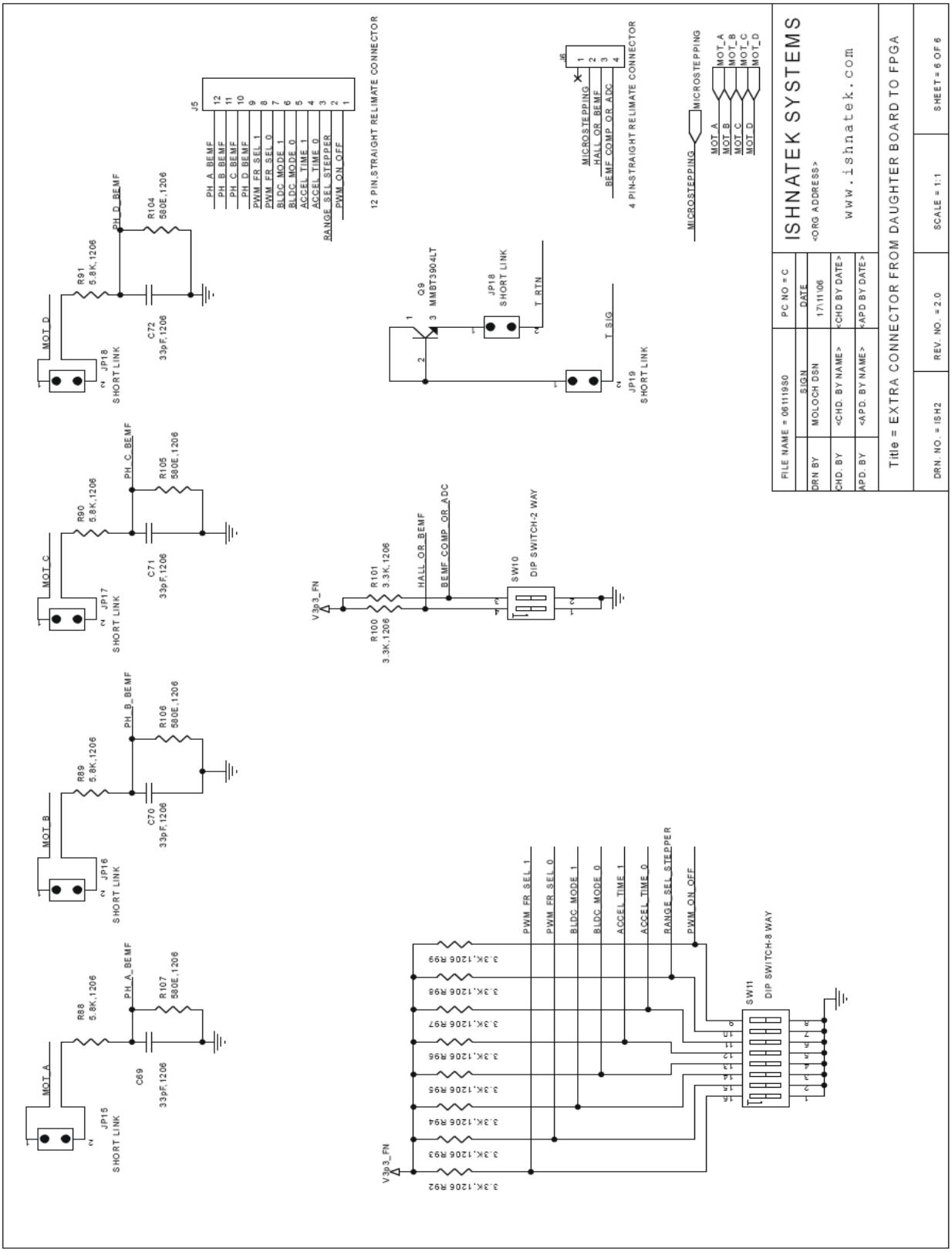


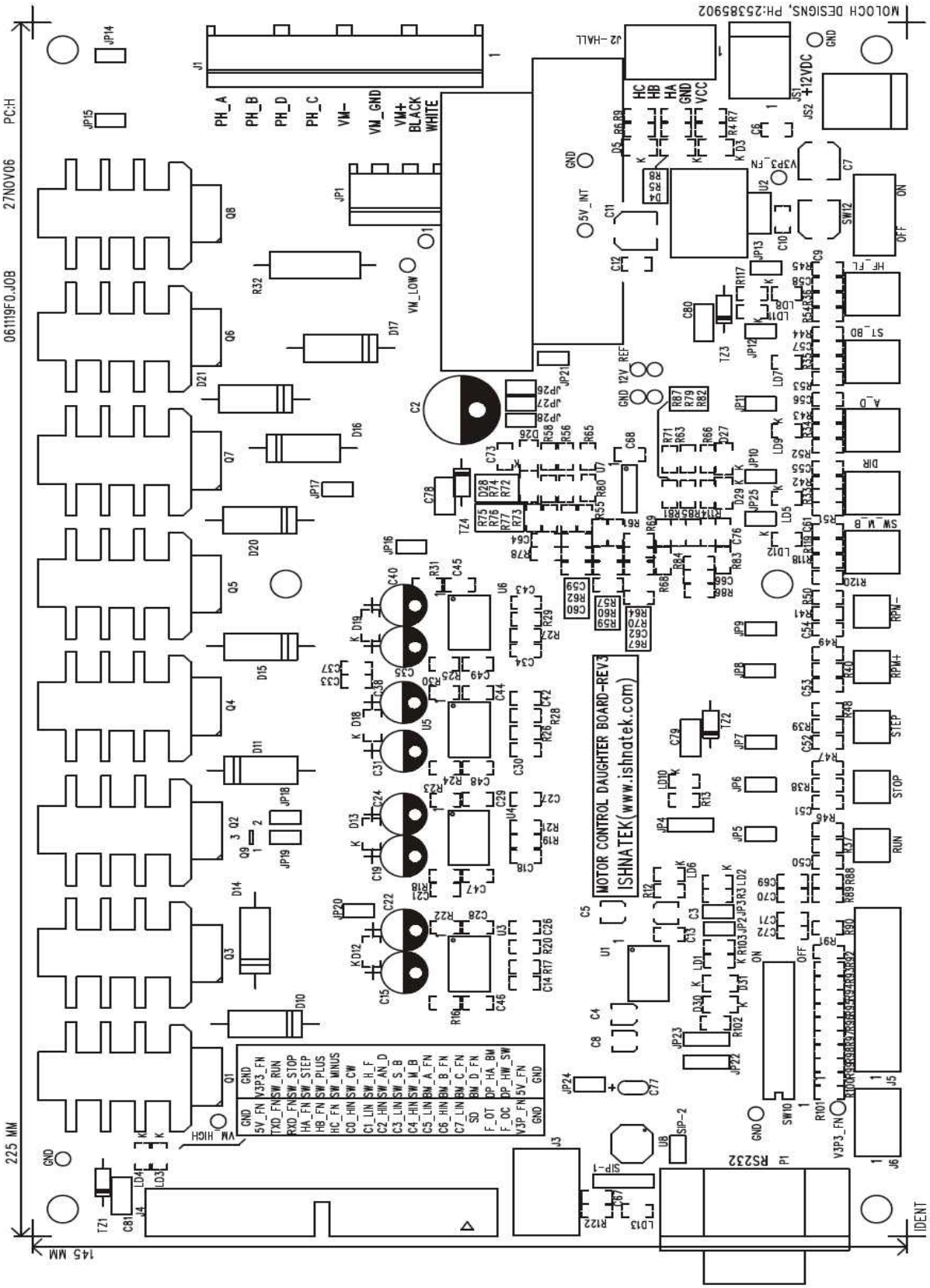

ISHNATEK SYSTEMS
<ORG ADDRESS>
www.ishnatek.com
Title = MOSFET DRIVERS AND MOSFET FULL-BRIDGE CIRCUIT
FILE NAME = 06111950
P/C NO = C
SIGN
DATE
DRN BY
MOLOCH DSN
17\11\06
CHD. BY
<CHD. BY NAME>
<CHD BY DATE>
APD. BY
<APD. BY NAME>
<APD BY DATE>
DRN. NO = ISH2
REV. NO = 2.0
SCALE = 1:1
SHEET = 2 OF 6
IRF3710,TO-220
IR2110,SO16W
1N4007,1206
6 Amp
6 AMP
VM_HIGH
VM_CS
12V_Ref
V3p3_FN
MOT_A
MOT_B
MOT_C
MOT_D
VM_LOW
VM_CS_AV1
VM_CS_AC1
0.01E,1W


ISHNATEK SYSTEMS
<ORG ADDRESS>
www.ishnatek.com
Title = SWITCHES/INPUTS TO FPGA FROM DAUGHTER CARD
FILE NAME = 061119S0
SIGN
DRN BY
MOLOCH DSN
CHD. BY
<CHD. BY NAME>
APD. BY
<APD. BY NAME>
PC NO = C
DATE
17\11\06
<CHD BY DATE>
<APD BY DATE>
DRN. NO. = ISH2
REV NO. = 2.0
SCALE = 1:1
SHEET = 3 OF 6
SW_RUN
SW_STOP
SW_STEP
SW_PLUS
SW_MINUS
SW_CW_CCW
SW_HLF_FUL
SW_AN_DIG
SW_STEP_BLDC
MICROSTEPPING
RUN
STOP
STEP
RPM+
RPM-
DIR
A_D
ST_BD
HF_FL
SHORT LINK
PRESS TO LATCH
SW DPDT/SM
6X6 TACK
LED.1206
V3p3_FN

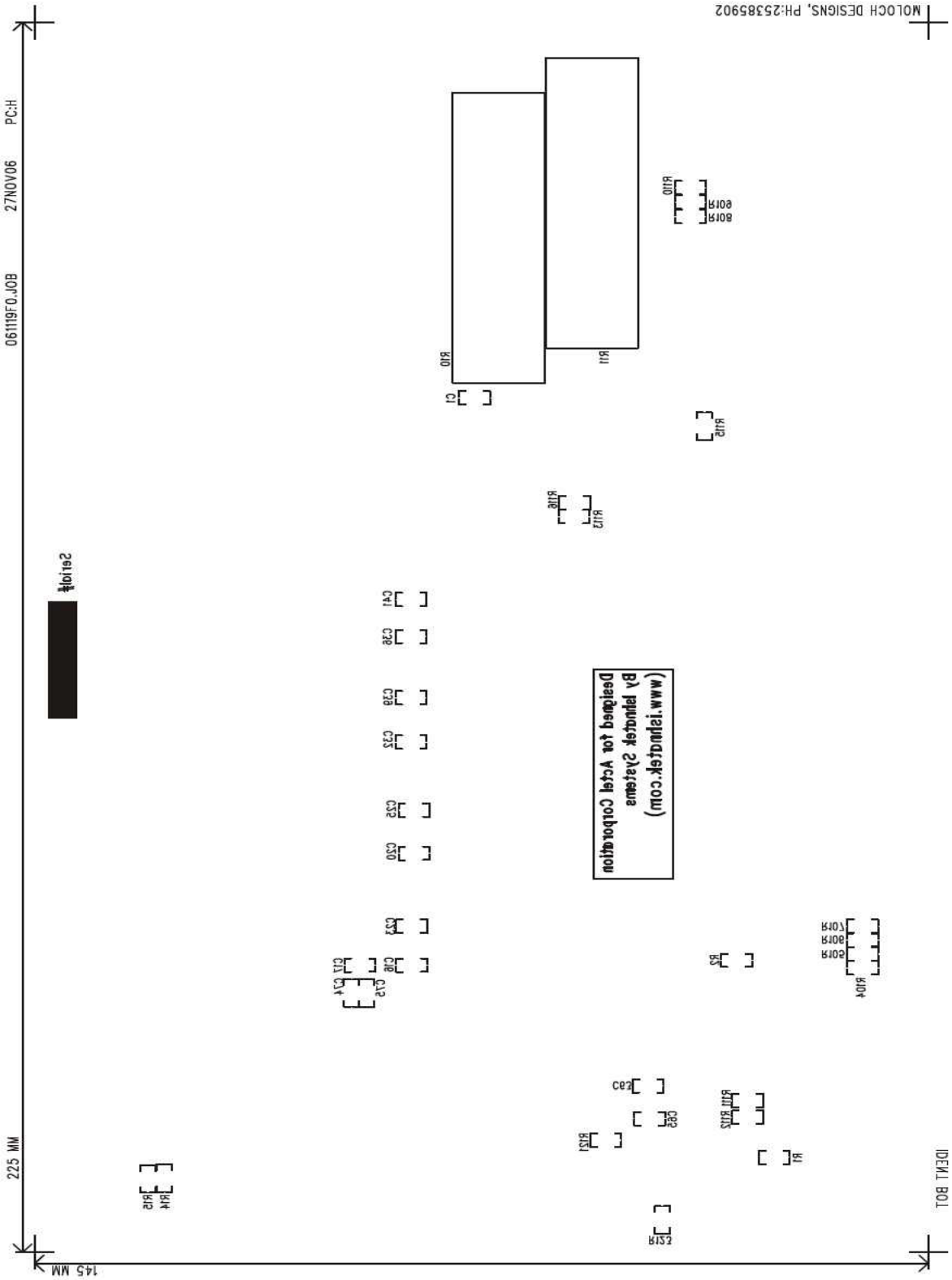

ISHNATEK SYSTEMS
www.ishnatek.com
Title = BEMF COMPARATOR CIRCUIT
LM339.SO14
1N4007.1206
MOT_A
MOT_B
MOT_C
MOT_D
BMFC_A_FN
BMFC_B_FN
BMFC_C_FN
BMFC_D_FN


ISHNATEK SYSTEMS
www.ishnatek.com
Title = CONNECTOR FROM FUSION BOARD TO DAUGHTER BOARD
20X2 HEADER-DUAL IN LINE
SHORT LINK
USB CONNECTOR
I/O VOLTAGE(3V)
CP2103


ISHNATEK SYSTEMS
www.ishnatek.com
Title = EXTRA CONNECTOR FROM DAUGHTER BOARD TO FPGA
12 PIN,STRAIGHT RELIMATE CONNECTOR
4 PIN-STRAIGHT RELIMATE CONNECTOR
MICROSTEPPING
DIP SWITCH-2 WAY
DIP SWITCH-8 WAY
SHORT LINK

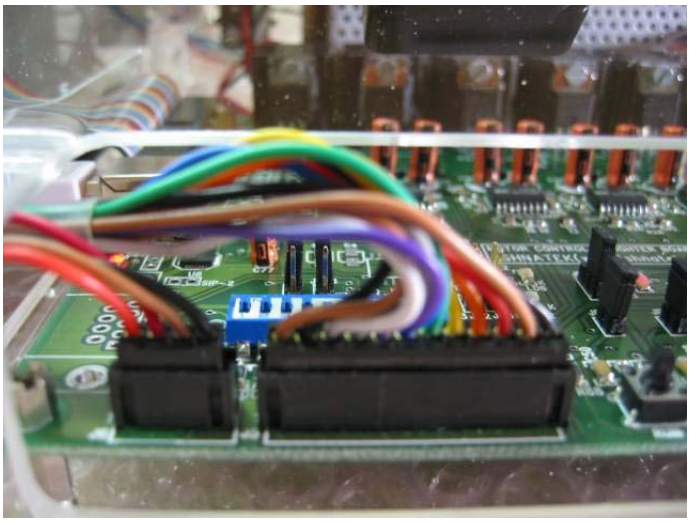

MOLOCH DESIGNS, PH:2538590
061119F0.JOB
27NOV06
PC:H
225 MM
145 MM
MOTOR CONTROL DAUGHTER BOARD-REV3
ISHNATEK(www.ishnatek.com)
PH_A
PH_B
PH_D
PH_C
VM-
VM_GND
VM+
BLACK
WHITE
HC
HB
HA
GND
VCC
+12VDC
RS232
IDENT

Ident – Top

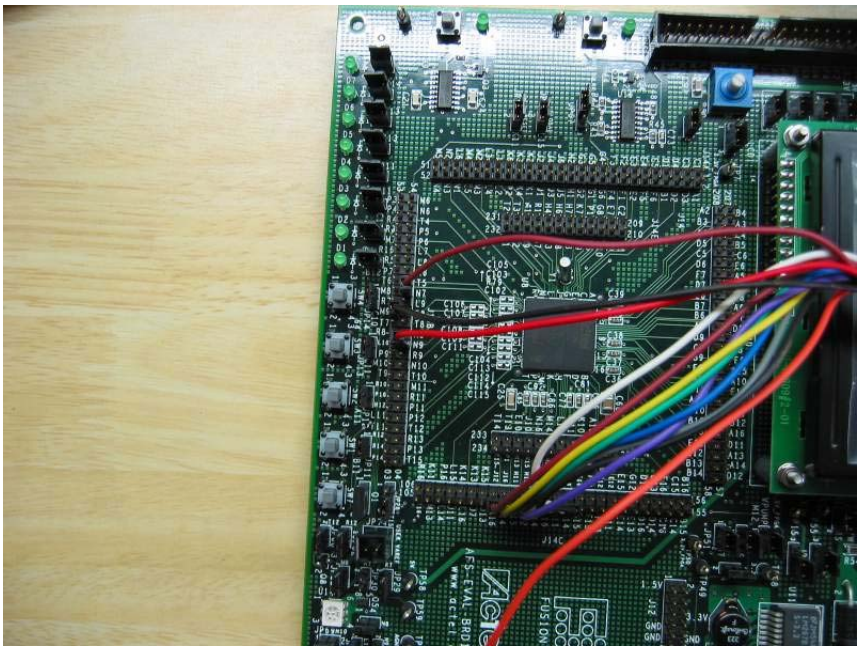


Ident – Bottom

9.4 Appendix – D Connection Pictures - Miscellenous:



CABLE-C and CABLE-D to Motor Control



CABLE-C and CABLE-D to FUSION

10. Contact Details:

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Suite #3-B, Devgiri
P.No. 117/1B, Kothrud Industrial Area
Pune 411029
Maharashtra, INDIA

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Fax: +91-20-25411579

Website: www.ishnatek.com
Support: support@ishnatek.com